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PROBLEMS OF PROVIDING JOINT OPERATION OF RADIO-ELECTRONIC EQUIPMENT

(Selected Portions)

by

A.D. Knyazev, V.F. Pchelkin

FOREIGN TECHNOLOGY DIVISION

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U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

GRAPHICS DISCLAIMER

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PROBLEMS OF PROVIDING JOINT OPERATION OF RADIO-ELECTRONIC EQUIPMENT.

A. D. Knyazev, V. F. Pchelkin.

Page 2.

Is examined number of questions, connected with resolution of problem of electromagnetic compatibility of radio-electronic equipment of different designation/purpose, caused by continuously growing requirement, for radio frequencies for RES with simultaneous increase in radiated power and increase in sensitivity of receiving devices. The part of the material is dedicated to questions of the distribution of radio frequencies. The examination of nonbasic/minority emissions of RES and nonbasic/minority channels of reception occupies large portion. Questions of the calculation of the levels of radio interferences are presented. For the first time in concentrated form, the existing norms and recommendations directed at the limitation of the level of radio interferences are given.

Pamphlet is designed for wide circle of radio specialists, who work in field of design, production and operation of RES and their HF elements, and also in instructors and students of radio engineering call.

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PREFACE.

One of problems, which appear during creation and operation of radio-electronic equipment, is guarantee of its joint operation with other equipment, which creates that mixing radio emission. As a result of the continuously increasing charging of radio-frequency ranges the urgency of this problem recently grew considerably. Its solution is especially complicated, when equipment works in the composition of the radio-electronic complex, whose elements are placed in immediate proximity. Subsequently this problem will only become complicated, if not to take the appropriate measures for its solution. Therefore important is the familiarization of the wide circle of radio specialists with the essence of problem the works, directed toward its resolution.

It is necessary to note that problem of electromagnetic compatibility is not new. However, its increasing complexity and the improvement of the methods of the solution lead to the new aspects. Many works of both the Soviet and the foreign are published on particular questions of electromagnetic compatibility. Unfortunately, however, these materials, until now, are not generalized.

The work being proposed to reader of "Engineering Library" [Biblioteka radioinzhenera"] is one of first generalizations of materials on problem in question.

Introduction, Chapters 2-4 were written by A. D. Knyazev; Chapters 1, 5-8 - by V. F. Pchelkin.

Authors with appreciation will accept all wishes and observations, which should be sent to publishing house "Sovetskoye radio".

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INTRODUCTION.

Continuous increase in quantity of radio-electronic equipment (RES), working, and limited possibilities of using radio-frequency ranges - contradictory factors of contemporary radio electronics. Working conditions of contemporary RES are characterized by the increasing level of the unpremeditated radio interferences from other RES and electrical devices/equipment of different designation/purpose. This is caused not only by an increase in the number of RES, but also by the spurious emissions of their transmitters, or by the property of their receiving devices to accept the emissions, which do not carry useful information, the channels of reception, which differ in the frequency from the working channel of these devices/equipment. All this limits the possibilities of guaranteeing the combined, simultaneous and independent from each other of the work of different RES.

Noted special features of work of contemporary RES brought as a whole to problem, which obtained name of electromagnetic compatibility (EMS) of RES. By this name is implied the concept about the totality of such properties of RES and the conditions for their work (providing space, frequency and time separation), under which it does not appear the interferences, which upset the operation of other RES, and normal operation on a certain interference level from other RES and different electrical devices/equipment at the same time is provided. Of course this problem is connected with general problem of increasing noise immunity of radio reception, but due to some special features, which will be examined in the following chapters, it has independent value.

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Problem of electromagnetic compatibility of RES is not new. The problems of the economical utilization of radio-frequency ranges and normalization of radio emissions have long ago been solved. Are known the numerous investigations of the methods of fight with the background radiation from RES and electrical devices/equipment, carried out by Soviet and foreign specialists. Is conducted extensive work on providing EMS of different systems of radio broadcasting and television, movable radio services and main-line radio links, radio-electronic equipment of ships and aircraft, etc. All-Union norms were developed and put into operation on frequency stability of the emission of transmitters, on the permissible interference levels from the electrical devices/equipment, to the width of the emission band of transmitters, etc. There are recommendations of international organizations MEK, MKKR [International Radio Consultative Committee], etc. regarding an improvement of EMS in radio-electronic equipment. In particular, are developed the recommendations of MKKR for the limitation of the power of radiation of that created by communication satellites by radio relay lines of sight.

It is not difficult to foresee that even in the near future problem EMS strongly will be complicated: possibility of isolation of free radio frequencies for new RES decreases and ever higher proves to be level of interferences between radio-electronic systems.

Continuous expansion of field of application of RES and increase in number and power of emitters advance new problems. It is necessary to develop/process the methods of the economical use of radio-frequency ranges; to create the engineering methods of calculation (forecasting) of the interference levels in the radio-electronic systems with the application of simulation of the electromagnetic situation in these systems. It is necessary to also investigate the sources of radio interferences, the methods of interference suppression in the place of their onset and the methods of reduction in the sensitivity of RES to interference. Should be expanded work on the normalization of the parameters of RES which affect EMS, and on the creation of standards, standards/normals and recommendations, aimed at the decrease of interference level.

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It is possible to conclude according to the data presented that problem of EMS encompasses wide region of radio electronics. This problem is connected with questions of the organization of the conditions for work of RES, using of the radio-frequency spectrum, radiowave propagation, forecasting of the possible interference levels and their spectral composition, construction of the radiotransmitter, radio-receiving and antenna systems, which ensure independent from the point of view of radio interferences work, the design resolutions of blocks, apparatuses and their elements (among other things of elements of filtration and shadowing) taking into account their arrangement/position as the component parts of the elaborate radio-electronic complex, development of the procedures of the measurement of the interferences and parameters iof RES, which affect their EMS, the creation of special measuring equipment and test equipment, etc. As a whole these questions can be divided into three groups:

- fundamental directions of resolution of problem of EMS,
- theoretical bases of providing EMS of RES;
- practical improvement in the conditions of EMS during the design, construction, in the production and during the operation of RES.

Unfortunately, problem of EMS, in spite of its urgency, insufficiently it is illuminated in Soviet literature. There are only a few periodical articles on particular questions of EMS. But literature, which generalizes works in this field, with the analysis of the level reached and further ways of resolution of problem is absent. Insignificantly is reflected this problem both in the training literature and also in the curricula of radio engineering VUZ [Institute of Higher Education] and technical schools. Therefore due to the insufficient information of the series/row of the specialists of radio electronics in questions of EMS the parameters of RES, which affect EMS, are frequently considered secondary.

This work does not pretend to filling of gap/spacing in existing literature. The authors pose the modest problem: to show the value of problem of EMS in contemporary radio electronics and to examine some ways of its resolution. The content of work can be divided into the following parts:

- essence of problem of EMS and questions of the use of ranges of radio frequencies;

- condition for work of RES from the point of view of providing EMS and the parameters of RES, which affect EMS;

- questions of the determination of the possible interference levels in the radio systems and the measurement of some parameters of RES, which affect their EMS.

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It must be noted that these areas do not encompass all questions of noise immunity of reception, methods of modulation, coding, demodulation and methods of processing signal accepted connected with optimization. Meanwhile the general/common properties, which ensure noise immunity of receiving device/equipment, are base for calculating the interference effect during the evaluation/estimate of EMS in the concrete/specific electromagnetic situation. This base, for example, can be the permissible threshold relation signal/noise. Nevertheless problem of EMS does not include general/common questions of noise immunity. Questions of EMS are limited by such organizational and technical and equipment answers, which in the complex are directed toward providing normal operation of RES, if they depend on the simultaneous and joint operation of other RES. It is possible that during creation and development of theory and practice of EMS its sphere will be expanded.

One should note also that concepts and terms, which relate to EMS, yet were not established/installed. Frequently for designation of the same concept different terms are utilized. Thus, for instance, used in this book term "electromagnetic compatibility" yet did not obtain wide acknowledgement. Another term "interferences" is not always valid; if it is possible to speak about the reciprocity of interferences between the complicated radio systems, then one cannot speak about the reciprocity of interferences between the receiver and the transmitter, since the receiver is not the source of interferences for the transmitter. These specific examples characterize the need for the creation of unified terminology in the field of EMS.

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1. ELECTROMAGNETIC COMPATIBILITY OF RADIO-ELECTRONIC EQUIPMENT AND THE DISTRIBUTION OF RADIO FREQUENCIES.

1.1. PROBLEM OF ELECTROMAGNETIC COMPATIBILITY OF RADIO-ELECTRONIC EQUIPMENT.

At present sharply has increased in all countries of terrestial globe and continues to increase the saturation of "ethers" by emissions of radio-electronic equipment which have different purpose, and also all possible electronic and other devices/equipment. Let us give the series/row of examples. A quantity of mobile radio units in the densely populated areas of almost all countries of terrestial globe is doubled every four years with the same bands of the frequencies, diverted for these stations [1]. The quantity of radio relay lines is increasing roughly as rapidly in a number of countries. Thus, whereas in 1963 in the USA were counted 7 thousand radio-relay stations, in 1968 it is expected that their number will increase to 17 thousand [2].

Quantity of radars (RLS), which are most powerful/thickest sources of interferences, even more rapidly increases. For example, in the USA in 1961 there were about 3 thousand RLS, and in 5 years (by 1966) there were almost 15 thousand of them. In this case only in the frequency band from 200 to 1000 MHz there were about 100 types of RLS, whose pulse power was from 100 kW to 60 MW. If one considers that weakening the antenna gain of these RLS for the lateral and rear lobes/lugs is 20-40 dB, then it is not difficult to rate/estimate the value of the interfering effect on other RES [3]. It should be noted that according to available data in Japan alone in one year a quantity of radio-electronic equipment increased by 25% and in 1965 composed 300 thousand [3].

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Let us point out also some promising data. Thus, by 1975 in the USA, for example, it is expected that the number of mobile transmitters will exceed 5 millions. It is assumed also that due to the speed, with which increases the overloading of the frequency bands, isolated for the satellite connection/communication, already to 1980 these bands will not satisfy requirement [4].

Besides increase in number and power of radio stations and radio-electronic equipment, considerably were complicated functions made by them. It is known, for example, that a considerable quantity of RES, works together with other RES, making general problems. Thus, for instance, radars of different designation/purpose, connected for the accomplishment of the objectives in the groupings assigned to them, cannot work without a large quantity of radio communications equipment (radio relay lines of sight, tropospheric radio relay lines, etc.). All these devices, as a rule, are placed over the limited area. Furthermore, over the same area or near can be arranged/located broadcast and television transmitters and large quantity of other radio-emitting equipment of different designation/purpose. In different orbits around the Earth there are a large number of ISZ [AES - artificial earth satellite], utilized for different targets, moreover, and this number with each year continuously increases. Each RES with the accomplishment of its objectives it emits and accepts the radio emissions, which for all remaining RES, which create this electromagnetic situation, are interfering.

In recent years of power of transmitters and antenna gain increased more than 10 times (together with this, naturally, it increased and level of supplementary and out-of-band emissions) [5]. The at present radio transmitting equipment are capable of generating the power, equal to hundred kilowatts in the continuous mode and to tens of megawatts in the pulse. Of this power it is sufficient in order to ensure radio communication to hundreds of millions of kilometers [6].

At the same time significantly rose sensitivity of receiving devices both along fundamental channel (contemporary radio receiving equipment they can accept signals with power on the order of 10^{-22} W) and along supplementary channels of reception.

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Furthermore, if one considers that a large part of the radio-frequency bands are very overloaded, and thus, more and more RES RES of different purposes must be placed in common frequency bands, it will become clear how intensely the interference levels which substantially decrease the tactical-technical characteristics of radio equipment, rose; sometimes they completely disrupt its normal operation. To such characteristics in radars, for example, relate the resolution, the probability of correct detection, precision characteristics, etc. [6, 7].

Scale of radio interferences can be judged, for example, from value of out-of-band emission of RES. According to the existing norms in the occupied frequency band are concentrated 99% of that emitted [8]. Consequently, the part of the power, equal to 1% of entire radiated power of signal, is the power of out-of-band emissions. On the contemporary levels of power this can compose the significant magnitude. For example, to the radio transmitters, which have the power, equal to ten kilowatts, this norm officially permits having the out-of-band emissions, equal to hundred watts. It is not difficult to represent, as they place to the work of the radio aids, whose receivers must accept the emissions, equal to the units of watts and milliwatts. The spurious radiations, whose level frequently insignificantly differs from the level of fundamental signal (for example, on 20 dB), also can create considerable interferences. These emissions, occupying the large frequency bands, for some stations compose tens of kilowatts on the third harmonic, hundreds of watts - on the fourth and tens of watts - at frequencies, arranged/located between the harmonics (spurious radiations) [7, 9, 10]. The value of the background radiation indicated is commensurate with net power of the transmitters of a large quantity of RES, and it sometimes considerably exceeds it. And even RES, which work in the diverse by several octaves frequency bands, it cannot be often placed at the close distances due to the possibility of the interfering effect. According to the given numerals the level of background radiation at the input of "foreign" receivers can exceed the level of useful signal, and the work of such receivers can prove to be impossible.

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Interference level can be judged also from value of emission by lateral and rear lobes of antenna radiation pattern of radar with pulse power, equal to 10 MW. With the contemporary level of the suppression of the emission of lateral and rear lobes/lugs, component on the order of 40 and 20 dB respectively, the antenna emits by minor lobes interference with the power of 100 kW, and rear lobes - 1 kW. Let us note that the pulse power of some contemporary radars reaches several hundred megawatts, and the amplification of their antennas approaches 60 dB [9]. And although the number of such stations is small, their enormous energy potential (more than 140 dBW) can cause considerable interferences, if we, of course, do not take the necessary measures for the decrease of the interfering effect of such stations.

Increase in quantity of movable equipment, equipped with radio-equipment, and voyages, completed by them, causes increase in mutual radio interferences. The quantity of radio equipment of ground-based movable radio links in the entire world must increase 2-fold from 1969 through 1972. Number of aircraft voyages in 1956. It equalled 65 thousand and by 1976 it will increase 12-fold; in 1970 there were 70 thousand commercial ships, and by 2000, 130 thousand of them are expected [21].

Finally, one should emphasize that emissions of radar and picture transmitters occupy considerable frequency bands. For example, for the cosinusoidal pulses (by duration $\tau_и$) the occupied frequency band is determined by expression $\Delta f_{эк} \approx 2{,}5/\tau_и$, for square pulses $\Delta f_{эп} \approx 20/\tau_и$, for the pulses of any other form width of occupied band is within the limits from $\Delta f_{эк}$ to $\Delta f_{эп}$. Thus, for example, high-frequency pulses with the duration of 1 μs occupy the frequency band from 2.5 to 20 MHz (depending on the shape of pulses) and can create in it interferences with other RLS.

Given examples, and also need of providing joint operation of radiolink systems with use of ISZ and radio relay lines of sight, which great partly work in overall frequency band, show that combined and simultaneous use of different RES can bring and it leads to electromagnetic incongruence of RES, which causes existence of problem of EMS of RES.

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Let us enumerate most characteristic unpremeditated radio interferences, which fall into radio receiving equipment.

First, this is the emission of RES, that work at one and the same or close with the radio station in question frequencies, when jamming frequency received by antenna falls in the passband of receiving device, and also analogous emissions, received by receiving device due to the insufficient frequency decoupling of working RES or due to the insufficient shadowing of receiving devices.

In the second place, such radio interferences include supplementary and out-of-band emissions of extraneous transmitters, which coincide in frequency with fundamental emission or which fall into passband of receiver. Furthermore, they include the background radiation, whose frequencies do not coincide with the passband of receiver, but they act on latter due to its inadequate selectivity (difference between the carrier frequencies of RES can equal several octaves), and also different emissions, which do not affect the receiver because of the presence of the channels of so-called supplementary reception, etc. It is obvious that the interfering signal will pass to the output of receiving device, if its power not less than the value, equal to the value of the real sensitivity of the supplementary channel of reception.

As illustration to aforesaid Fig. 1.1 shows amplitude-frequency characteristic [1] of receiver A(f), on which acts interference, and spectral characteristic of transmitter $Э(f)$, which creates interference.

FOOTNOTE [1]. Measuring equipment does not make it possible to plot true curve, and in the figure zero level indicates the level of the sensitivity of measuring meter. ENDFOOTNOTE.

From the figure one can see that besides the normal band of transmission $\Delta f_{\text{пр}}$ the receiver has a number of discrete bands of transparency, caused by different reasons, including the presence of supplementary channels of reception $\Delta f_{\text{поб}}$. The frequency of tuning receiver $f_{\text{пр}}$ does not coincide with carrier frequency $f_{\text{нес}}$ of transmitter, and, in spite of this, interference is passed to the receiver along all channels of reception.

Thirdly, unpremeditated radio interferences include industrial radio interferences, i.e., interferences, created by any devices/equipment, except radio transmitting equipment of RES: interference from industrial, medical and scientific high- frequency installations, from electrical instruments, from transportation equipment, electric power lines, systems of scannings/sweeps of cathode-ray tubes, etc.

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Industrial interferences, as a rule, through electrical networks of alternating current, through the feed circuits of radio installations and directly (in the case of the close arrangement of the sources of interferences) act on the elements of receiver.

It should be noted that during evaluation/estimate of possibility of providing EMS of two or more radio-electronic equipment some researchers compose so-called frequency charts. These charts are the totality of the characteristics of all background radiation and characteristics of the reception of these emissions along any channels of reception (fundamental channel, any supplementary channel of reception), constructed for these devices. Best proves to be the version, with one characteristic it does not coincide with another, i.e., with which are absent the frequency coincidences of the interfering signals with the channels of reception of the radio equipment of the interacting radio aids. However, since virtually this it is not possible to attain, then one should approach the minimum frequency coincidences of the interfering signals with the channels of reception of radio equipment.

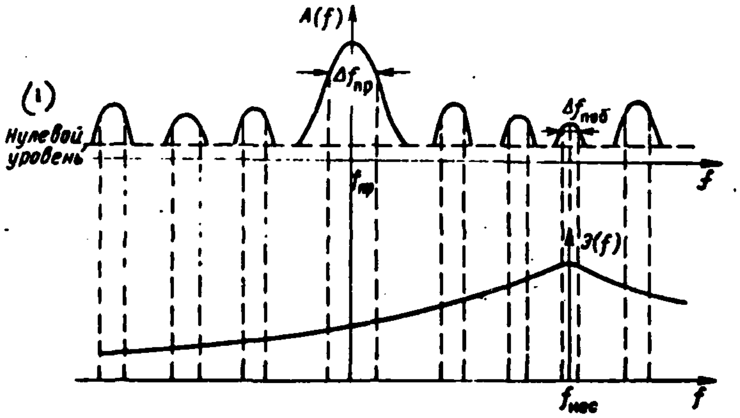

Fig. 1.1. Key: (1). Zero level.

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Since rational distribution of radio frequencies between RES is one of methods of resolution of problem of electromagnetic compatibility of RES, let us pass to examination of number of questions, connected with distribution of radio frequencies.

1.2. CLASSIFICATION OF RADIO FREQUENCIES AND RADIO WAVES.

Spectrum of electromagnetic vibrations encompass frequencies approximately from 10^{-3} to 10^{22}-10^{23} Hz. Part of the electromagnetic oscillations, from 3 Hz to 3000 GHz, are occupied by radio frequencies, which are in turn divided into 12 frequency bands. At present still there is no steady classification of the ranges of radio frequencies and radio waves. Therefore during the development of Soviet terminology will be proposed the classification (see Appendix [11]), in which are used the corresponding recommendations of the "regulations of radio communication" [8].

By range of radio frequencies should be understood region of radio frequencies, which encompasses specific frequencies. Each of the ranges stretches from $0{,}3 \times 10^N$ to $3 \cdot 10^N$ Hz, where N=1, 2, 3, ..., 12 - number of range. By range of radio frequencies should be understood also the region of radio frequencies with other (large) frequency boundaries in the limits indicated, determined organizational or technical considerations. Sometimes concept "range of radio frequencies" they confuse with the concept "radio- frequency band". Radio-frequency band - also the region of radio frequencies, but it can be the part of one range or partly adjacent ranges of radio frequencies.

In order to rate/estimate sizes/dimensions of all ranges of radio frequencies, let us say that if each telephone channel occupies band with width of 4 kHz, then all radio-frequency ranges can provide simultaneous transmission in limited territory of 750 mln. telephone channels. These channels can be used not only by one country, but also with the series/row of the countries or by all countries simultaneously. At present distribution and use of radio frequencies is complex problem. However, in the first years of the development of radio communication [1], when were not yet needed frequencies for the radar, radio navigation, radio controls, radiotelemetry, televisions, etc., and telephone and telegraph communications in essence were transmitted by the wires and coaxial cables, which did not require the use of radio frequencies, serious problem of the question of distribution and use of radio frequencies there did not exist.

FOOTNOTE [1]. By this term, according to the "regulations of radio communication", should be understood transmission or reception of any kind of signals (text, images, sounds or other communications/reports), be it radar or television, radio-telephone or radiotelegraph, etc., with the use of radio waves. ENDFOOTNOTE.

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During the first stage (approximately up to 1918 in radio telegraphy), kilometer waves (long) were utilized. In the second stage, which was lasting approximately up to 1940, were mastered hectometer and decametric wave bands (average/mean and short waves). Appeared radio broadcasting, radio communication, television, radar, radio navigation, etc. And finally in the contemporary stage were mastered also the rest of the radio wave bands. Furthermore, was begun the mastery/adoption of the bands of the electromagnetic vibrations, not included by the radio-frequency ranges (infrared rays, optical range, ultraviolet, X-ray and γ-rays) [12].

Need for use of ever shorter waves can be shown based on example. Three ranges - kilometer, hectameter and decametric waves - occupy in entire radio-spectrum of approximately 30 MHz, sufficient only for 12 communication systems, with capacity/capacitance of 600 telephone channels each. Actually, one such system (with one telephone channel, which occupies the frequency band, equal to 5 kHz) will require 2.4 MHz (600·4 kHz=2.4 MHz), and 12 systems - 28.8 MHz. Thus, shape, virtually for other radiolink systems in these ranges of "vacant place" it will no longer prove to be.

Thus, at present continues to be expanded range of mastered radio frequencies, continuously they increase requirement for radio-electronic equipment of different designation/purpose and power of their radiations, is raised sensitivity of radio receiving equipment. All this calls an increase in the radio interferences of RES. Therefore is necessary the corresponding control during the distribution and during the use of radio frequencies both within the country and in the international scale. It must be noted that the first international conference, which was taking place in 1927, made a decision about the regulation of the use of radio frequencies only in the small frequency band from 10 Hz to 60 MHz. In 20 years, in 1947, the maximum frequency, which was regulated by the international union of electrical communication, it was raised with 60 MHz to 10.5 GHz. At present the frequency-allocation table between the radio services, accepted in the "regulations of radio communication", encompasses range from 10 kHz to 40 GHz. Let us note also that virtually the ranges of radio waves, until now, are not still completely mastered, although the evolution of their mastery/adoption is undoubted. Thus, for instance, upper boundary of the frequencies, most utilized in the radio stations, in comparison with 1920 increased by more than four orders (1000 kHz - in 1920 and 12 GHz - at present) [13].

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1.3. SOME QUESTIONS OF DISTRIBUTION AND USE OF RADIO FREQUENCIES.

1.3.1. General questions of selection of frequency bands.

For distributing frequency bands terrestial globe is divided into three areas. Into area 1 enter all countries of Europe and Africa, and also Mongolia, the Asian part of the territory of the USSR and the part of the territory of Turkey. North and South America and Greenland occupy area 2. Area 3 encompasses the countries of Asia (with exception of the Asian part of the territory of the USSR, Mongolia and part of the territory of Turkey), Australia and oceania [8].

During distribution and use of radio frequencies should be distinguished with concepts - distribution, appropriation and frequency discrimination or frequency bands. Concept "distribution" relates to the services, concept "isolation/liberation" - to the zones or the countries, concept "appropriation" - to stations [8].

Scientific-technical and organizational principles are necessary for rational solution of questions of distribution and use of radio-frequency ranges. Such principles at present are not completely yet developed, and their development is one of the most important problems of the electromagnetic compatibility of radio-electronic equipment.

During selection of one or the other frequency band for appropriation to its concrete/specific transmitter it is necessary first of all to focus attention on special feature of radiowave propagation of different ranges. For example, for guaranteeing the global radio communication should be selected the myriametric waves, which 24-hour are propagated around the Earth. For the same purpose are suitable kilometer waves. To main disadvantages in these wave bands should be related: the need of applying the antenna systems with the very large overall sizes also of the very large power of transmitters, difficulty of obtaining the sharp/acute directivity of antennae, small capacity due to a small width of frequency range (to the myriametric waves - only 27 kHz, to kilometer 270 kHz) and presence of strong atmospheric and industrial radio interferences.

Hectometer waves (width of frequency range it is 2.7 MHz) have the same deficiencies and advantages that kilometer, but in less expressed form.

Decametric waves (width of frequency range it is 27 MHz) due to reflection from ionosphere are propagated along earth's surface and they permit implemention of global radio communication. Main disadvantage in this wave band is the presence of strong signal fading due to the interference of waves, caused variously of their arrival.

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Ultrashort waves (width of frequency range it is 270 MHz) are propagated virtually in line-of-sight ranges. In this range the level of atmospheric and industrial radio interferences falls, but it is nevertheless very great (it is compared with the internally-produced noise of receivers). Interferences from the galaxy and the sun also become significant.

Decimeter waves (width of frequency range it is 2.7 GHz), and also centimeter (27 GHz) are most favorable for their application for diverse purposes during transmission to large distances. In these ranges the radio waves are propagated, as a rule, in the line-of-sight ranges. However, due to the tropospheric scattering of radio waves a connection/communication can be realized up to the large distances (to 1000 km). In these ranges relaying with the aid of the radio-relay stations and the artificial Earth satellites received wide acceptance. It is necessary to note also the possibility of obtaining the large power (tens of megawatts in the pulsed operation and tens of kilowatts in the continuous mode), the possibility of the realization of the pencil-beam antennas with the small overall sizes of the latter, the absence (approximately at frequencies of above 1000 MHz) of man-made interferences, a comparatively small dependence of weakening the radio waves (at frequencies of below 10 GHz) during their propagation from the meteorological conditions (in essence, from the fog, rain, snow, clouds, from the time of days and year, etc.). Radiowave propagation with the frequencies is above 10 GHz, including the propagation of the millimeter radio waves, which encompass the enormous frequency range, equal to 270 GHz, strongly it depends on the enumerated meteorological conditions. Frequencies and the frequency bands in this range should be selected, knowing the regions of the transparency of the atmosphere for the radio waves and the regions of their strong weakening.

Submillimetric waves, which occupy enormous frequency range, equal to 2700 GHz, at present virtually little mastered.

Fig. 1.2 shows value of effect of atmosphere and degree of study of effect of atmosphere on fundamental modes of propagation of electromagnetic waves (to frequency of 10^{15} Hz).

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On the axis of abscissas are indicated the values of the effect of the atmosphere (upper rectangles) and the degree of study of this effect (lower rectangles) for different mechanisms of the propagation: 1 - in the troposphere in the line-of-sight ranges; 2 - waveguide in the troposphere and reflected from it; 3 - tropospheric scattering; 4 - propagation in the line-of-sight ranges on the route the Earth - space; 5 - waveguide in the region the Earth to the ionosphere and the ionospheric reflection; 6 - ionospheric scattering; 7 - scattering by the ionospheric traces of meteors.

Fig. 1.3 illustrates possibility of forecasting effect of ionosphere on fundamental mechanisms of propagation of electromagnetic waves. Numerals on the axis of abscissas correspond to the types of the mechanisms of propagation, indicated in Fig. 1.2.

During selection of desirable frequency bands should be considered presence of necessary generator and receiving electric vacuum and semiconductor devices.

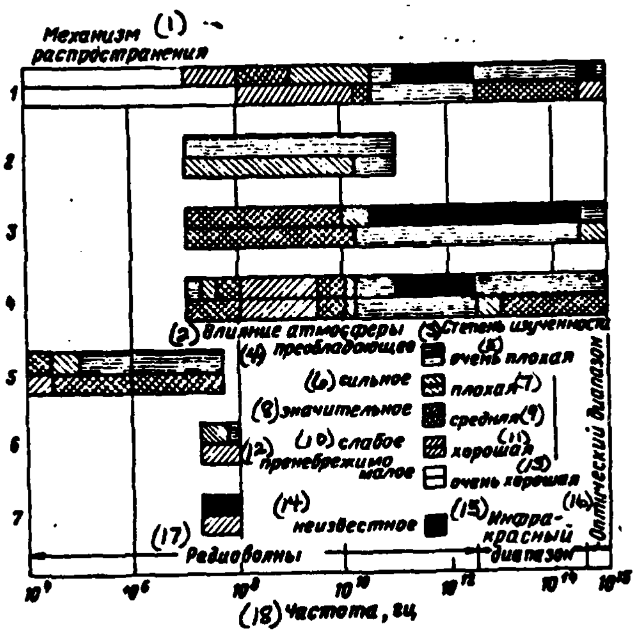

Fig. 1.2. Key: (1). Mechanism of propagation. (2). Effect of atmosphere. (3). Degree of study. (4). predominating. (5). very poor. (6). strong. (7). poor. (8). considerable. (9). average/mean. (10). weak. (11). good. (12). negligible. (13). very good. (14). unknown. (15). Infrared region. (16). Optical range. (17). Radio waves., (18). Frequency, Hz.

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In conclusion let us enumerate possible applications of radio waves of different ranges. Deca-kilometer and decametric waves widely are used for the global radio communication, kilometer, hectometer and decametric - for radio communication and sonic radio broadcasting, meter - for the radio communication, the television and the radio astronomy, decimeter and microwaves - for the radar, the radio navigation, the radio control, the radio communication (including space), radio astronomy, etc. Millimeter and submillimetric waves can be utilized for the space communication, and also in the waveguide lines of communications, which changes in the meteorological conditions do not affect.

Now let us pause at order, necessary during distribution of radio frequencies.

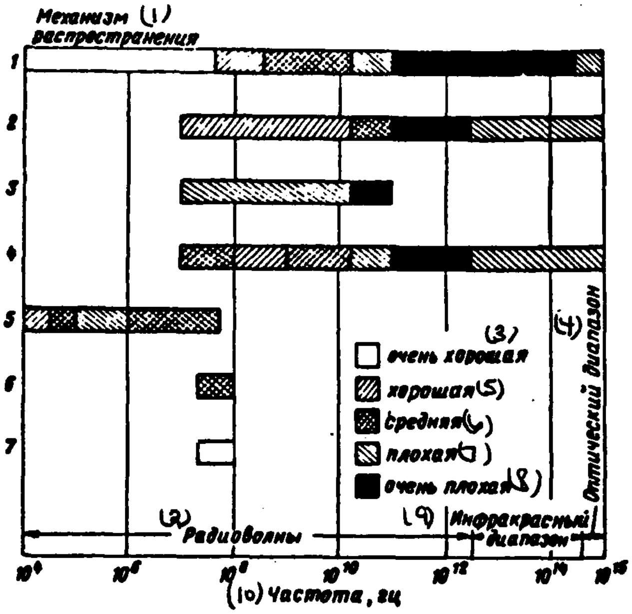

Fig. 1.3.

Key: (1). Mechanism of propagation. (2). Radio waves. (3). very good. (4). Optical range. (5). good. (6). average/mean. (7). poor. (8). very poor. (9). Infrared region. (10). Frequency, Hz.

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This order includes: distribution and the account of the use of separate bands of frequencies and separate frequencies of all radio-frequency ranges between all radio services (they must be determined condition and the principles of the combined use of individual sections of frequency ranges by radio-electronic means of different designation/purpose); control/checking of the routine of the use of radio frequencies; radio control after the radio emissions; development, acceptance and the distribution of the necessary rules and instructions, necessary for all, who utilize radio frequencies or, even if he does not utilize them, it can create radio interferences, and finally in the case of the disturbance/breakdown of these rules and instructions the stopping of development or production of radio-electronic means and electrical equipment.

Besides organizational principles indicated, to clients of new devices/equipment and developers of latter should be paid considerable attention to methods and to means of suppression or decrease of radio interferences: to filtration; to shadowing, to special diagrams of suppression; included in receivers or in source of interferences; to improvement in antenna directivity; to contraction of band of frequencies of transmitted signals (this it does not relate to wide-band signals); to application of new methods of modulation, special attachments, etc. It is necessary to also perform work on reduction in the interferences, for example by the construction of the transmitting devices RES with the decreased level of spurious radiations, by the construction of receiving devices RES with the lowered/reduced level of the sensitivity of the channels of supplementary reception, by developing the powerful vacuum-tube instruments (magnetrons, amplitrons, amplifier klystrons, mitrons, LOV, LBV, etc.) with the decreased level of spurious radiations, etc.

1.3.2. On the principles of the appropriation of the frequency bands for the television and VHF FM broadcasting in the meter range of radio waves.

Let us examine some questions, which relate to distribution of radio frequencies for television and VHF FM broadcasting in meter range of radiowaves [14]. For these purposes are utilized the following frequency bands: 48.5-66; 76-100, 174-230 MHz (television) and 66-73 MHz (VHF FM broadcasting). Table 1.1 gives the distribution of these bands for the television with the indication of the carrier frequencies of the channels of image and sonic tracking, accepted in the Soviet Union, Bulgaria, Hungary, Poland, Rumania and Czechoslovakia. Recently for the purposes indicated was begun the use of the decimeter range, in which according to "Regulations of radio communication" was isolated the band of frequencies of 470-960 MHz; the band of frequencies of 11.7-12.7 GHz, isolated in the centimeter band for sonic radio broadcasting and television, in practice it is utilized still little.

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For VHF FM broadcasting in band of frequencies of 66-73 MHz in enumerated countries, and in Albania is also utilized set of 80 frequencies for transmission of four programs. This number is caused by the need for providing continuous maintenance/servicing of territory of country by general routine VHF FM broadcasting. During the distribution of operating frequencies for the transmitters, modulated by the identical program, necessary the frequency separation, equal to 60 kHz, is counted, for the transmitters, modulated by different programs, equal to 120 kHz. With this separation, as practice showed, at the transmitters power from 3.5 to

7.5 kW and the height of antenna supports of approximately 200 m for the continuous maintenance/servicing must be about 20 operating frequencies. Under this condition for the transmission of one general routine is necessary the band of frequencies 20·0.06=1.2 MHz, and for the transmission of local programs 20·0.12=24 MHz. Consequently, diverted for VHF FM broadcasting band of frequencies of 7 MHz is sufficient in order to place four programs in it; three state values (union 1, union 2 and republic), which require the frequency band, equal to 3.6 MHz, and one the local importance (regional), the requiring frequency band, equal to 2.4 MHz.

Comparing data, given in Table 1.1, with data of distribution of frequency bands for television in series/row of countries (FRG, Yugoslavia, Norway, Sweden, Italy) closely spaced with USSR given in Table 1.2, it is possible to judge difficulties, which appear during distribution of bands of frequencies (especially with agreement of concrete/specific national plans/layouts boundary areas from point of view of EMS) indicated. Let us note that the European countries, besides those enumerated, for VHF FM broadcasting utilize a band of frequencies of 87.5-100 MHz.

Thus, frequency band, occupied by television channel in one group of European countries, is 8 MHz (see Table 1.1), in another - 7 MHz (Table 1.2). The deviation of frequency is equal to ±50 and ±75 kHz respectively for VHF FM broadcasting and sonic tracking of television.

Table 1.1.

(1) Канал	(2) Полоса частот, Мгц	(3) Несущая частота, Мгц	
		(4) канал изображения	(5) канал звукового сопровождения
ТВ-1	48,5—56,5	49,75	56,25
ТВ-2	58—66	59,25	65,75
ТВ-3	76—84	77,25	83,75
ТВ-4	84—92	85,25	91,75
ТВ-5	92—100	93,25	99,75
ТВ-6	174—182	175,25	181,75
ТВ-7	182—190	183,25	189,75
ТВ-8	190—198	191,25	197,75
ТВ-9	198—206	199,25	205,75
ТВ-10	206—214	207,25	213,75
ТВ-11	214—222	215,25	221,75
ТВ-12	222—230	223,25	229,75

Key: (1). Channel. (2). Band of frequencies, MHz. (3). Carrier frequency, MHz. (4). channel of image. (5). sound channel.

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Noted special features create considerable difficulties during development of principles of engineering planning of television and VHF FM broadcast networks both in territory of each country and with agreement of national plans/layouts between adjacent countries due to limitations, connected with elimination of radio interferences.

Let us enumerate fundamental problems, which should be solved during allocation of frequencies in this case. First, in the zone of servicing the corresponding transmitter it is necessary to provide the field strength, required for the confident reception, in the second place, it is necessary to determine the minimum frequency and territorial separations between the adjacent transmitters, with which during the assigned period of time (in the percentages) are provided the required ratio of signal to the interference, thirdly, during the construction of the transmitting and receiving television and VHF FM broadcast networks it is necessary to consider economic indices.

Field strength in frequency bands in question depends on value of radiated power, wavelength, distance between transmitter and receiver, distance of straight/direct visibility between antennas of latter/last, meteorological conditions and area relief. Usually are distinguished four zones of the field distribution around the transmitter: near zone, the zone of diffraction field, the zone of tropospheric field and the zone of ionospheric field, each of which does not have sharply pronounced boundaries. The dependence of the field strength at a distance of R from the radiation source in these zones at the radiated power half-wave dipole 1 kW and different height of its suspension is given in Fig. 1.4 [14]. Dotted line showed a change in the field strength during the radiowave propagation in the free space from the half-wave dipole. This field intensity is calculated from the formula

$$E_0 = \frac{2{,}22 \cdot 10^5}{d} \frac{\text{мкв}}{\text{м}}{}^{(1)},$$

Key: (1). μV/m.

where d, km - distance from the transmitter.

Table 1.2.

(1) Канал	(2) Полоса частот, Мгц	(3) Несущая частота, Мгц	
		(4) канал изображения	(5) канал звукового сопровождения
E-1	40—47	41,25	46,75
E-2	47—54	48,25	53,75
E-3	54—61	55,25	60,75
E-4	61—68	62,25	67,75
E-5	174—181	175,25	180,75
E-6	181—188	182,25	187,75
E-7	188—195	189,25	194,75
E-8	195—202	196,25	201,75
E-9	202—209	203,25	208,75
E-10	209—216	210,25	215,75
E-11	216—223	217,25	222,75

Key: (1). Channel. (2). Band of frequencies, MHz. (3). Carrier frequency, MHz. (4). channel of image. (5). sound channel.

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Near zone follows zone of diffraction field, whose intensity/strength at a distance of R can be found about to graphs/curves of International Radio Consultative Committee (MKKR). On these graphs/curves is determined the strength of the field, exceeded during 1, 10, 50, 90 and 99% of time for frequencies 60, 100 and 200 MHz at the height of the transmitting antenna (of type half-wave dipole) from 50 to 1500 m. In this case is considered that the power, emitted by transmitter, is 1 kW, and the height of receiving antenna 10 m. The field strength in this zone decreases monotonically with the removal/distance from the transmitter. The zone of diffraction field continues to the radio horizon, which virtually corresponds to the distance of straight/direct visibility between the point of reception and the point of transmission.

Tropospheric zone following after diffraction is characterized by large changes in field strength, difference between its maximum and minimum values can reach 40 dB. the strength of tropospheric field can be determined also according to the graphs/curves of MKKR.

Between diffraction and tropospheric fields is located zone of fading (fading) in which strengths of these fields become commensurate. And finally should be noted the zone of ionospheric field, caused by reflection from the ionized layers of the atmosphere of the radio waves, the strength of field of which is determined on by those corresponding to graphs/curves.

Without stopping on determination of field strength, let us examine shielding relation, which is one of fundamental indices, considered with planning of television transmitting networks and VHF FM broadcasting. By shielding relation $K_{\text{защ}}$ is understood the minimally necessary ratio of the value of useful signal to sound level, which provides the reception of information with the assigned quality.

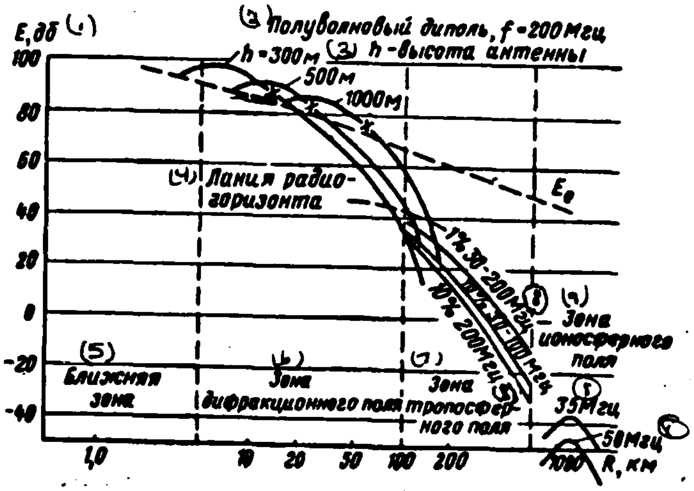

Fig. 1.4.

Key: (1). dB. (2). Half-wave dipole, f=200 MHz. (2). h - height of antenna. (4). Line of radio horizon. (5). Near zone. (6). Zone of diffraction field. (7). Zone of tropospheric field. (8). MHz. (9). Zone of ionospheric field.

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Shielding relations are obtained experimentally and are recommended by MKKR and OIRT for identical antenna polarization of jamming transmitter and receiver of useful signals. If antenna polarization is different, then the required shielding relations decrease on 10 dB. If the interfering and useful transmitters work at the identical carrier frequency, then shielding relations depend on the kind of their work (television, VHF FM broadcasting or AM broadcasting); if frequencies are spread, then also from the selectivity of receiver.

For television with work of interfering and useful transmitters at identical carrier frequencies shielding relation is 45 dB. The fulfillment of this norm requires the large three-dimensional/space separation between the transmitters (to several hundred kilometers). For fulfilling of the recommendation indicated and decreasing the necessary three-dimensional/space separation should be changed carrier frequency of one of the transmitters on 10-12 kHz with respect to the carrier frequency of another transmitter, which composes approximately 2/3 and 3/4 from the frequency of line scanning $f_{стр.}$ equal to 15.625 kHz.

Let us explain, why with this detuning of transmitters the television receiver is less sensitive to interfering signal. The fact is that picture signal, as is known, is formed/shaped due to the processes of scanning/sweep with the frame frequency and rows and therefore it consists of discrete/digital frequency components, multiple to frame frequency and to line-scanning frequency. When picture signals from two picture transmitters come into the receiver, then due to the beating between the carrier frequencies of the images of these transmitters interferences appear. And their value changes in the dependence on the difference between the carrier frequencies. The greatest interferences correspond to the odd harmonics of field repetition rate (with the more rapid changes) and to the harmonics of horizontal frequency (with the slower), the smallest interferences are necessary to the even harmonics of field repetition rate and for the frequencies, multiple for half of horizontal frequency. Consequently, if a difference in the carrier frequencies of two picture transmitters is equal to any even harmonic of field repetition rate and is close to half of horizontal frequency, then the interferences of these transmitters will be smallest. The smallest interferences are obtained on 312-th and 314-th harmonics of the field repetition rate, which correspond to frequencies 7800 and by 7850 Hz, which are nearest to half of horizontal frequency, i.e., to 7812 Hz.

Table 1.3 gives shielding relations for black and white television during different biases/displacements of carrier frequency of transmitters (SNCh), which work in those combined, i.e., in identical channels.

Table 1.3.

СНЧ	(1) В долях строчной частоты	$\frac{1}{12}$	$\frac{1}{6}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{5}{12}$	$\frac{1}{2}$	$\frac{7}{12}$	$\frac{2}{3}$	$\frac{3}{4}$	$\frac{5}{6}$	$\frac{11}{12}$
	(2) В кгц	1,3	2,6	3,9	5,2	6,5	7,8	9,1	10,4	11,7	13,0	14,3
(3) Защитное отношение, дб		41	38	34	30	27	26	27	30	34	38	41

Key: (1). In the portions of horizontal frequency. (2). In kHz. (3). Shielding relation, dB.

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It is evident from the table that with SNCh, equal to 1/2 horizontal frequencies (7.8 kHz), shielding relation can be smallest. However, it should be noted that in practice commonly is used SNCh, equal to 2/3 or 4/3 ordered frequencies. In this case for servicing the assigned area usually three picture transmitters, that work in one frequency channel, are arranged/located in the apexes/vertexes of triangle. Carrier frequency of one of these transmitters is equal to the carrier frequency of the channel of the image of television channel $f_{нес}$ given in Table 1.1, the carrier frequency of another is equal to $f_{нес}+\frac{2}{3}f_{стр}$, the third - $f_{нес}-\frac{2}{3}f_{стр}$; the carrier frequencies of the second and third transmitters they differ to 4/3 $f_{стр}$. Let us note also that if one of three transmitters is the transmitter for color television, then the required shielding relation with SNCh, equal to 2/3 horizontal frequencies, must be not 30, but 33 dB.

Let us show based on example, such as gain gives application of bias/displacement of carrier frequency. If we do not use bias, then the three-dimensional/space separation, equal to 450 km, is necessary for the picture transmitters (at the height of antennas 200 m) with a power of 2 kW for guaranteeing the required field strength on the boundary of the zones of their maintenance/servicing (500 μV/m). With the bias of the carrier frequency for 2/3 horizontal frequencies the transmitters can be drawn nearer each other to 320 km, i.e. the application of SNCh reduces three-dimensional/space separation almost by 30%.

Given requirements for shielding relations are valid for television with work in combined channels. If work occurs the extra-combined channels, then interferences can appear with the work of picture transmitters at frequencies, located in the band of the channel of image with the work of other transmitters, which have another television standard and another grid of frequencies (or with the work of the transmitters of another designation/purpose), and also out of the band of the channel of image (in adjacent channels). For the first case the dependence of shielding relation on detuning Δf of receiver relative to the carrier frequency of the jamming transmitter, which occupies the frequency band, which corresponds to the selected television channel, is given in Fig. 1.5. This dependence has asymmetric character right branch (corresponding to passband of receiver) is caused by the difference of the number of rows of resolution and by the properties of kinescope, left branch - also by the selective properties of receiver. In the second case of interference they appear as a result of the beating between the frequencies of the radiation spectrum of jamming transmitters (for example, transmitters of VHF FM broadcasting) and the carrier frequencies of the channels of image and sound (for example, in channels TV-2 and TV-3).

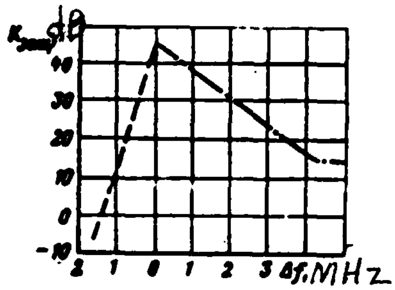

Fig. 1.5.

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Without examining in detail this case, let us note that for adjacent television [transmitters one ought not to use frequency of adjacent television channels.

It is necessary to also consider that with television reception not only another transmitters can be sources of interferences, but also heterodynes of television sets. Thus, at intermediate frequency 34, 25 MHz the heterodyne of the television set, which accepts transmission at the frequency of channel TV-1, can create interferences with the reception of transmission at the frequency of channel TV-5; the heterodyne of the television set, which accepts TV-6, with the reception at the frequency of channel TV-10; the heterodyne of the television set, which accepts transmission at frequency TV-7, with the reception at the frequency of channel TV-11 and the heterodyne of the television set, which accepts TV-8, with the reception of transmission at the frequency of channel TV-12.

Therefore one ought not to allow/assume the enumerated combinations in one zone of maintenance/servicing during the guarantee with its multiprogramming television.

Now let us examine, what shielding relations are necessary for VHF FM broadcasting. Their values depend mainly on the power of jamming transmitter and on the value of the separation between the frequency adopted and the frequency of jamming transmitter. When separation does not exceed 20 kHz, i.e., it is found in the range of audio frequencies, interference is developed as interference whistle, if the carrier frequency is not modulated; the program adopted is distorted in the presence of modulation. Therefore the guarantee of a frequency separation is the first requirement, equal not less than 20 kHz. In this case the dependence of the recommended by MKKR shielding relations on the separation of frequencies with different character of the programs of the interfering and useful transmitters is given in Fig. 1.6. From the figure one can see that with the separation of frequencies to 20 kHz the shielding relation must be maximum (30 dB). With an increase in the separation, when decreases the power of the radiation spectrum of the jamming transmitter, which enters the passband of receiver, is required smaller shielding relation. With the work of the transmitters, modulated by general routine, from the separation of frequencies, equal to 100 kHz, this shielding relation falls to 0 ~~db;~~ dB; with modulation this relation is provided by different programs with the frequency separation 200 kHz. Let us note that for the Soviet receivers the shielding relation, equal to 0 ~~db,~~ dB, is provided with the frequency separation, equal to 120 kHz, if both transmitters are modulated by one program, and 180 kHz during the transmission of different broadcast programs.

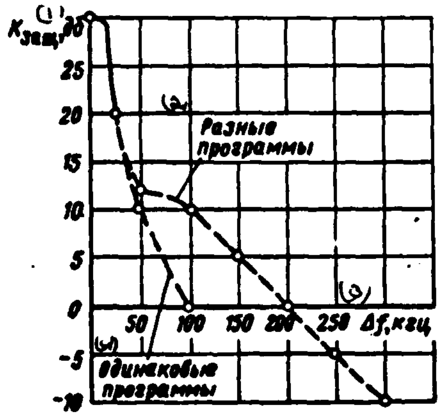

Fig. 1.6.

Key: (1). dB. (2). Different programs. (3). kHz. (4). Identical programs.

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One should consider that in practice at input of receiver of VHF FM broadcasting can enter two interfering signals: one - from adjacent transmitter, to another from that more distant. The recommended shielding relations with two jamming transmitters ensuring satisfactory reception, are given in Table 1.4.

Let us switch over to definition of useful zone of transmitter, which is characterized by boundary strength of field $E_{гр}$. i.e. by field strength on boundary of zone of maintenance/servicing, which ensures required ratio of signal to interference.

Boundary field strength, in reference to 1 kW of power of radiation (graphs/curves of field strength they are designed with respect to power of radiation of half-wave dipole, equal to 1 kW), is equal to

$$E^{1}_{rp} = 20\lg E_{r\theta} - 10\lg P_{\Sigma},$$

where P_{Σ} — effective power, emitted by antenna, kW. after finding value E^{1}_{rp}, according to the graphs/curves of radiowave propagation it is possible to define the zone of servicing transmitter.

Taking into account requirement of high quality of reception and sensitivity of produced by industry mass receivers (100-200 μV for television and 50 μV for VHF FM broadcast), depending on frequency band and place of reception are accepted corresponding values of boundary field strength. In regional and large industrial centers value of boundary field strength it is 5 mV/m for television in all ranges; this simultaneously provides normal reception and VHF FM broadcasting. In the rural locality/terrain for the television in the range 48.5-100 MHz boundary intensity/strength at the level of timing pulses must be 54 dBμV/m, or 500 μV/m; in the range 174-230 MHz - 57 dBμV/m or 700 μV/m; for VHF FM broadcasting - 46 dBμV/m, or 200 μV/m (height of receiving antenna is equal to 10 m).

In practice useful zone of transmitter, as a rule, in essence depends on interferences, created by located hereabout transmitters, which have the same or close to frequency of this transmitter emission frequency. In connection with this is used this concept, as the shielded field strength, always exceeding the boundary field strength.

Table 1.4.

(1) Разнос несущих частот, кгц	(2) Разная программа	0	30	60	90	120	150	180	240	300	360
	(3) Одинаковая программа	0	30	60	90	—	—	120	—	—	—
(4) Защитное отношение, дб		31	27	20	12	10	4	0	—5	—10	—15

Key: (1). Separation of carrier frequencies, kHz. (2). Different program. (3). Identical program. (4). Shielding relation, dB.

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Therefore by zone of the maintenance/servicing transmitter is understood the territory, on boundary of which the field strength, caused by the emission of transmitter, during the preset time (in the percentages) to the value of shielding relation is more than the value of total interferences from the jamming transmitters.

Since interfering effect of transmitters depends from their distance to boundary of useful zone of maintenance/servicing, during distribution of radio frequencies for television and VHF FM broadcasting it is necessary to correctly select frequencies of transmitters and distance between transmitters so that shielded field strength on boundary of zone of maintenance/servicing would be minimally permissible.

Finally, it should be noted that interfering effect of transmitters, as a rule, is developed due to tropospheric propagation, which is characterized by nonuniformity in time. Therefore is established/installed norm to the so-called temporary/time coefficient, which determines the duration of interference in the percentages, with which the relation of field from the transmitter to the interfering field adopted will be equal or less than the assigned shielding relation. The recommended temporary/time coefficient composes 10% with the authenticity, equal to 90%.

Let us pause at calculation procedure, used with planning of networks of television and VHF FM broadcasting [14]. This procedure is based on the rational selection of frequency channel for the transmitter in question and on the calculation of the zone of maintenance/servicing, created by transmitter, on boundary of which the probability of cumulative effect of interferences from other transmitters must not be higher than the assigned magnitude.

Let us examine method of calculation of zone of maintenance/servicing under influence on receiver of interfering signals. So that the broadcasting would be qualitative, at any point of the zone of maintenance/servicing, as already mentioned, must be provided necessary shielding relation $K_{\text{защ}}$. A quantity of points of reception, at which during the specific time (in percent) is provided qualitative reception (in spite of interferences from other transmitters), it is determined on coefficient $K_{\text{расст}}$, which is located with the aid of the following formula (all values in the decibels):

$$K_{\text{расст}}=K_{\text{защ}}-P_{\text{раб}}+P_{\text{меш}}-E_{\text{раб}}(50,50)+E_{\text{меш}}(50,50), \quad (1.1)$$

where $K_{\text{расст}}$ — coefficient, which considers the statistical field distribution at different points of reception at the assigned distance of R from the transmitter for the averaged locality/terrain; $P_{раб}$ — the effective radiated power of the working transmitter of relatively 1 kW; $P_{пом}$ — the same for the jamming transmitter; $E_{раб}$ (50, 50) - the median (average/mean) value of the field strength, created by working transmitter at the assigned distance of R_1 and exceeded during 50% of time of observation for 50% of points of reception at the effective radiated power of half-wave dipole, equal to 1 kW; $E_{пом}$ (50, 50 - the same from the jamming transmitter at a distance of R_2.

Equation (1.1) is fundamental during gliding/planning of transmitting networks of television and VHF FM broadcasting. Into it enter five parameters, three of which are determined on the curves of propagation [14].

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The first of them - the shielding relation, during determination of which the strength of the field of useful signal is received as median, i.e. is located according to the graphs/curves of propagation, comprised for 50% of time, and the noise field intensity must be determined on propagation curves, which correspond to 10% of time. On propagation curves for 50% of time are determined the two additional parameters: $E_{раб}$ (50, 50) and $E_{пом}$ (50, 50). Fig. 1.7 and 1.8 for an example give such curves for the frequency of 60 MHz (λ=5 m), on which E_0 - field strength in the free space, h_a - height/altitude of the lift of the transmitting antenna.

Thus, according to formula (1.1) is defined $K_{расст.}$ and then zone of servicing of useful transmitter. It is the territory, on boundaries of which the required shielding relation during the preset time of qualitative reception, is provided, and it is determined on the radii, at ends/leads of which is provided this relation. In formula (1.1) are substituted the values of the field strength from the useful and jamming transmitters, determined in the place of reception at the appropriate distances from these transmitters (R_1 and R_2).

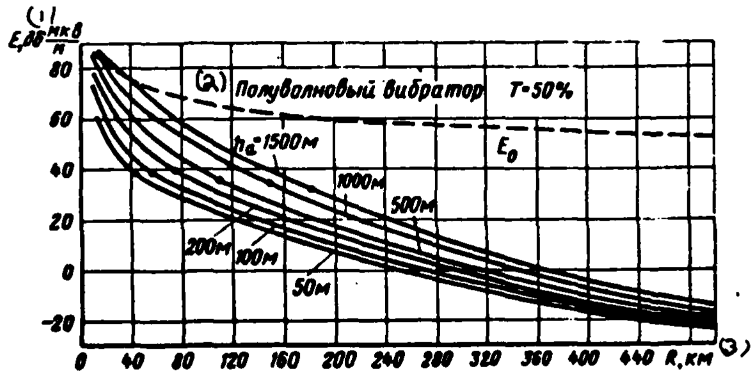

Fig. 1.7.

Key: (1). dB μV/m. (2). Half-wave dipole. (3). km.

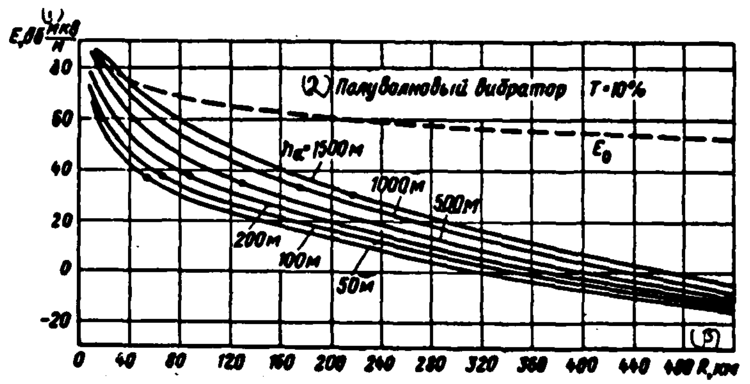

Fig. 1.8.

Key: (1). dB μV/m. (2). Half-wave dipole. (3). km.

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According to that calculated $K_{расст}$ with the aid of the graph/curve of the propagation (for the frequency of 60 MHz it it is given in Fig. 1.9), where Δh - height/altitude of the lift of the transmitting antenna above the territory of maintenance/servicing) is determined a quantity of points of reception l(%), that lie at the zone of maintenance/servicing at a distance of R_1 from the transmitter and ensuring shielding relation $K_{защ}$ during the preset time. $K_{расст}$ for other radial directions is located after this. Welding of these radii, we obtain the curve, which is the boundary of the zone of servicing transmitter.

Value l is called probability of guaranteeing qualitative conditions of reception during interference of one transmitter. Analogous probability $(l_1, l_2, \ldots, l_n)$, is found with the presence of jamming transmitters for each of them, and reception without the interferences during T% with time is provided by the probability, equal to the product of these probabilities, i.e.

$$L(R, T) \approx l_1 l_2 \ldots l_n = \prod_{i=1}^{n} l_i.$$

This formula would be valid, if there would be no time correlation between strengths of fields of jamming transmitters, i.e. if they were varied conditions for radiowave propagation, which arrive into point of reception from different directions. However, this correlation exists due to the tropospheric propagation.

Radii of servicing transmitter in series/row of directions are determined with several jamming transmitters, i.e., in each selected direction is found the distance, which corresponds to probability of guaranteeing qualitative reception in several jamming transmitters L(R, T), equal to, as a rule, 0.45%. This means that during assigned percentage of time (T%) 45% of points of reception has qualitative reception. The ends/leads of such radii give the curve, which is the boundary of the unknown zone of maintenance/servicing.

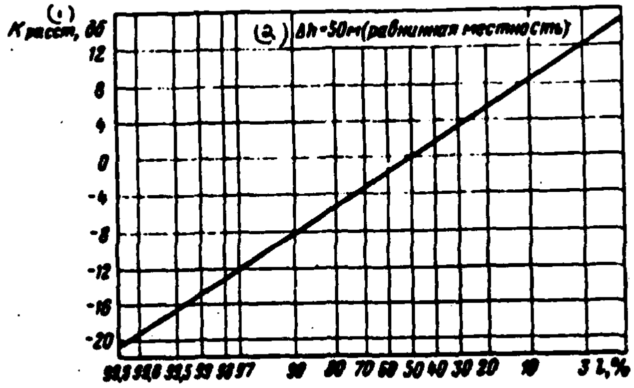

Fig. 1.9.

Key: (1). dB. (2). Δh=50 m (flat terrain).

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The method indicated gives the reduced, i.e., more guaranteed zone of servicing transmitter. Let us note that the method of calculation of the zone of maintenance/servicing with one jamming transmitter gives the increased zone, i.e., that less guaranteed. And the more the jamming transmitters considered, the greater proves to be the difference during the calculation of the zone of maintenance/servicing, obtained according to both methods.

1.4. INTERNATIONAL ORGANIZATIONS AND CONFERENCES ON THE ELECTROMAGNETIC COMPATIBILITY OF RADIO-ELECTRONIC MEANS AND THE DISTRIBUTION OF RADIO FREQUENCIES.

Largest international organizations, connected with distribution and use of radio frequencies, are international union of electrical communication (MSE), international special committee on radio interferences (SISPR), international committee on marine radio communications (MKMRS), international scientific radio-union (URSI), international organization of radio broadcasting and television (OIRT), international organization of civil aviation (MOGA), European union of radio broadcasting, etc. Only international organization, having the right/law to solve the problems of the distribution of radio frequencies, is the international union of electrical communication, members of which on 1 January, 1969, are 133 countries. At present MSE is the special organ of the United Nations, whose staff office is located in Geneva.

MSE has following organizational structure:

1. Plenipotentiary conference, which is the supreme organ/control of Union.

2. Administrative radio-conference.

3. Administrative conference on telegraphy and telephony.

4. Permanent organs of MSE:

A. General secretariat.

B. International committee of recording frequencies (MKRCh).

C. International radio consultative committee (MKKR).

D. International consultative committee on telegraph and telephon (MKKTT).

1.4.1. Regulations of radio communication.

The main international document on questions of distribution of radio frequencies is regulations of radio communication, accepted by administrative conference of radio communication in Geneva into 1959 [8] and collectors/collections of positions being, which determine use of radio-spectrum and work of radio services, including allocation of frequencies, order of use of frequencies, norm to radio emissions, measures of fight against radio interferences, rules of work of separate radio services, etc.

In this document is given determination of large quantity of terms (more than 100), which relate to radio systems, to services, to stations and to technical characteristics (frequency, width of occupied band, necessary bandwidth, spurious radiation, interference, power, antenna gain, antenna radiation pattern, etc.).

In it also is examined classification of emissions and frequency bands, utilized for radio communication.

Fundamental place in "regulations of radio communication" occupies "frequency-allocation table between 10 kHz and 40 GHz", that consists of three graphs/counts, that correspond to three areas. In each graph of table is indicated the appropriated frequency band and the category of services (in the alphabetical order according to French names), which include the given distribution. If one and the same frequency band is appropriated to several services, then in the table first are indicated "primary", then the "permitted", and then "secondary" services. However, primary services have seniority rights of the selection of frequencies before those permitted during the composition of the plans/layouts of allocation of frequencies. Of the station of secondary services, on one hand, they must not create the inadmissible interferences with the stations of primary and permitted services, and on the other, they themselves do not have the right/law to present claim to the interferences from the stations of primary or permitted of services, although they have a right/law to present such claims to the stations of secondary service.

In 1966 the international union of electrical communication published the regularly reprinted (after supplements and changes) "frequency-allocation table from 10 kHz to 40 GHz". It consists of five separate tables for all three areas of terrestial globe.

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Table 1 encompasses range from 10 to 7000 kHz; Table 2 - range from 7000 kHz to 108 MHz; Table 3 - from 108 to 960 MHz; Table 4 - from 960 to 8500 MHz; Table 5 - from 8.5 to 40 GHz [7]. Table shows, as radio frequencies between the separate services are distributed. Among them - the fixed/recorded, ground-based movable, marine movable, air movable, marine radio navigation, air radio navigation, radar, radio broadcasting, amateur services, standard frequencies, radio astronomy, radio navigation, radio navigation with the aid of ISZ [artificial earth satellite], weather satellites, space investigations, radio communication with the help of ISZ, etc.

In "Regulations of radio communication" are given resolutions, which relate to appropriation and use of frequencies, and also to separate services (radio broadcasting, air movable service, air radio beacons, marine mobile service, marine radio beacons and fixed/recorded service), they are examined questions, connected with claim and recording of frequencies and with work of international committee of recording frequencies, about which it will be described separately.

Special position in "Regulations of radio communication" is assigned to materials, which relate to limitation of interferences.

It is assumed that if we during appropriation of frequencies to radio stations adhere to "Frequency-allocation table" and to observe resolutions of "Regulations of radio communication" and series/row between people agreements, part from which will be further given, then it is possible to expect guarantee of electromagnetic compatibility between radio stations of adjacent countries. The frequency, appropriated to the radio station of this service, must not be arranged/located near the boundaries of the frequency band, isolated for this service. Otherwise the part of the frequency band, assigned to this radio station, can prove to be in the adjacent frequency band, isolated to another service, which can lead to the electromagnetic incongruence.

One should emphasize that is forbidden any emission, which can create inadmissible interferences with distress signals and call in radiotelephony at international frequencies of calamity, equal to 500 kHz (it is used by stations of marine, airships and rescue facilities, which use frequencies in permitted bands 405-535 kHz) or 2182 kHz (it is used by stations of the same vessels and means, which use frequencies in bands 1605-4000 kHz).

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Table 1.5.

(1) Служба	(2) Мириаметровые волны, 10—30 кгц	(3) Километровые волны, 30—300 кгц	(4) Гектометровые волны, 300—3000 кгц	(5) Декаметровые волны, 3—30 Мгц
(6) Радионавигация	10—14	70—130	—	—
(7) Радиолокация	(7a) 10—14 (в)	—	—	—
(8) Радиовещание	—	150—285	525—1605; 2300—2498	3,2—3,4; 3,95—4,0; 4,75—4,995; 5,95—6,2; 7,1—7,3; 9,5—9,775; 11,7—11,975; 15,1—15,45; 17,7—17,9; 21,45—21,75; 25,6—26,1
(9) Фиксированная	14—19,95; 20,05—30	30—70; 72—84; 86—112; 115—126; 129—130; 130—150 (р)	1605—2170; 2194—2498; 2502—2625; 2650—2850	3,155—3,4; 3,5—3,9; 3,95—4,063; 4,438—4,65; 4,75—4,995; 5,005—5,48; 5,73—5,95; 6,765—7,0; 7,3—8,195; 9,04—9,5; 9,775—9,995; 10,1—11,175; 11,4—11,7; 11,975—12,33; 13,36—14,0; 14,35—14,99; 15,45—16,46; 17,36—17,7; 18,03—19,99; 20,01—21,0; 21,75—21,85; 22,72—23,2; 23,35—24,99; 25,01—25,07; 25,11—25,6; 26,1—27,5; 29,7—30,0

Key: (1). Service. (2). myriametric waves, 10-30 kHz. (3). Kilometer waves, 30-300 kHz (4). Hectometer waves, 300-3000 MHz. (6). Radio navigation. (7). Radar. (7a). V. (8). Radio broadcasting. (9). Fixed/recorded.

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Cont'd Tabl. 1.5.

(1) Метровые волны, 30—300 Мгц	(2) Дециметровые волны, 300—3000 Мгц	(3) Сантиметровые волны, 3—30 Ггц	(4) Миллиметровые волны, 30—40 Ггц
—	582—606; 2900—3000	3—3,1; 5,46—5,47; 9,3—9,5; 14—14,4; 24,25—25,25	31,8—33,4
—	420—430 (в); (5) 430—440; 440—450 (в); (5) 890—942 (в); (5) 1215—1300; 1300—1350 (в); (5) 1350—1400; 2300—2550 (в); (5) 2700—3000 (в); (5)	3—3,1 (в); (5) 3,1—3,4; 3,4—3,6 (в); (5) 5,25—5,35; 5,35—5,65 (в); (5) 5,65—5,85; 8,5—9,0; 9,0—9,2 (в); (5) 9,2—9,3; 9,3—9,5 (в); (5) 9,5—10,5; 10,5—10,68 (в); (5) 13,4—14,0; 15,7—17,7; 23—24,25	33,4—36
41—68; 87,5—100; 174—223	470—960	11,7—12,7	—
30—41; (5) 41—47 (в); 68,0—74,8; 75,2—87,5; 138—137; 145—149,9; (5) 180,05—174; 223—235 (в); 235—300	300—328,6; 335,4—399,9; 401—406 (в); (5) 403—430; 440—470; 790—960; 1350—1400; 1427—1535; 1670—1690; 1690—1700(в); 1700—2690	3,4—4,2; 4,4—5; 5,85—7,25; 7,3—7,975; 8,025—8,5; 9,8—10 (в); (5) 10,5—10,68; 10,7—13,25; 14,4—15,25; 17,7—19,3; 19,4—21; 22—23; 25,25—30	30—31,5; 31,5—31,8 (в); (5) 36—40

Key: (1). Ultrashort waves 30-300 MHz. (2). Decimeter waves, 300-3000 MHz. (3). Microwaves, 3-30 GHz. (4). Millimeter waves, 30-40 GHz. (5). V.

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Cont'd Tabl. 1.5.

(1) Служба	(2) мириаметровые волны, 10—30 кгц	(3) Километровые волны, 30—300 кгц	(4) Гектометровые волны, 300—3000 кгц	(5) Декаметровые волны, 3—30 Мгц
(6) Морская подвижная	14—19,95; 20,05—30	30—70; 72—84; 86—112; 115—126; 129—160; 255—285	415—490; 510—525; 1605—2498; 2625—2650	4,063—4,438; 6,2—6,525; 8,195—8,815; 12,33—13,2; 16,46—17,36; 22,0—22,72; 25,07—25,11
(7) Стандартные частоты	19,95—20,05	—	2498—2502	4,995—5,005; 9,995—10,005; 14,99—15,01; 19,99—20,01; 24,99—25,10
(8) Любители	—	—	—	3,5—3,8; 7,0—7,1; 14,0—14,35; 21,0—21,45; 28,0—29,7
(9) Воздушная радионавигация	—	255—285; (9a) 285—300 (в)	(9a) 300—315 (в); 315—415; (9a) 510—525 (в)	—
(10) Морская радионавигация	—	285—300	300—315; 405—415; 2625—2650	—
(11) Воздушная подвижная (вп)	—	—	(9a) 325—405 (в); — 2850—3000 (R)	3—3,025 (R); 3,025—3,155 (OR; 3,4—3,5 (R); 3,8—3,95 (OR; 4,65—4,7 (R); 4,7—4,85 (OR; 5,43—5,48 (OR; 5,48—5,68 (R); 5,68—5,73 (OR; 6,525—6,685 (R; 6,685—6,765 (OR; 8,815—8,965 (R; 8,965—9,04 (OR; 10,005—10,1 (R); 11,175—11,275 (OR; 11,275—11,4 (R) 13,2—13,26 (OR; 13,26—13,36 (R; 15,01—15,1 (OR; 17,9—17,97 (R; 17,97—18,03 (OR; 21,85—22 (R); 23,2—23,35 (OR

Key: (1). Service. (2). myriametric waves 10-30 kHz. (3). Kilometer waves, 30-300 kHz. (4). Hectometer waves 300-3000 kHz. (5). Decametric waves, 3-30 MHz. (6). Marine mobile. (7). Standard frequencies. (8). Amateurs. (9). Air Air movable (VP).

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Cont'd Tabl. 1.5.

(1) Метровые волны, 30—300 *Мгц*	(2) Дециметровые волны, 300—3000 *Мгц*	(3) Сантиметровые волны, 3—30 *Ггц*	(4) Миллиметровые волны, 30—40 *Ггц*
—	—	—	—
—	—	—	—
144—146	430—440; (5) 1215—1300 (в); 2300—2450 (в) (5)	5,65—5,85 (в); (5) 10—10,5 (в) (5) 21—22	—
74,8—75,2; 108—117,975; 216—235	328,6—335,4; 960—1215; 1300—1350; 1535—1660; 2700—2900	4,2—4,4; 5—5,25; 5,35—5,46; 8,75—8,85; 9—9,2; 13,25—13,4; 15,4—15,7	—
—	—	5,47—5,65	—
—	—	—	—

Key: (1). Ultrashort waves, 30-300 MHz. (2). Decimeter waves 300-3000 MHz (3). Microwaves, 3-30 GHz. (4). Millimeter waves, 30-40 GHz. (5). v.

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Cont'd Tabl. 1.5.

(1) Служба	(2) мириаметровые волны, 10—30 кгц	(3) Километровые волны, 30—300 кгц	(4) Гектометровые волны, 300—3000 кгц	(5) Декаметровые волны, 3—30 Мгц
(6) Радиометеорология	—	—	2045—2065	27,5—28
(7) Подвижная	—	—	405—415; (8) (кроме вп); 490—510; (10) (сигналы бедствия и вызова); 2000—2065 (8) (кроме вп): 2065—2170; (8) (кроме вп R); 2170—2194 (10) (сигналы бедствия и вызова); 2194—2498 (9) (кроме R); 2502—2625 (9) (кроме R) 2625—2850 (9) (кроме R)	3,155—3,23 (9) (кроме R); 3,23—3,4 (8) (кроме вп); (8) 3,5—3,8 (кроме вп); 4,438—4,65 (кроме R); 25,01—25,07 (кроме вп); 25,11—25,6 (9) (кроме вп); 26,1—27,5 (9) (кроме вп); 29,7—30
(11) Наземная подвижная	—	—	—	3,8—3,9; 4,75—4,995; 5,25—5,48; 23,35—24,99
(12) Воздушная фиксированная	—	—	—	21,85—22,0; 23,20—23,35
(13) Радиоастрономия	—	—	—	—
(14) Космические исследования	—	—	—	(14a) 15,762—15,768 (в); 18,03—18,036 (в); (14a)
(15) Космическая	—	—	—	—
(16) Связь с помощью ИСЗ	—	—	—	—
(17) Радионавигация с помощью ИСЗ	—	—	—	—
(18) Радиометеорология с помощью ИСЗ	—	—	—	—

Key: (1). Service. (2). myriametric waves, 10-30 kHz. (3). Kilometer waves, 30-300 kHz. (4). Hectometer waves, 300-3000 kHz. (5). Decametric waves, 3-30 MHz. (6). Radiometeorology. (7). Movable. (8). besides VP. (9). besides R. (10). signals of distress and call; (11). Ground-based movable. (12). Air fixed/recorded. (13). Radio astronomy. (14). Space investigations. (14a). V. (15). Space. (16). Connection/communication with the aid of ISZ. (17). Radio navigation with the aid of ISZ. (18). Radiometeorology with the aid of ISZ.

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Cont'd Tabl. 1.5.

(1) Метровые волны, 30—300 *Мгц*	(2) Дециметровые волны, 300—3000 *Мгц*	(3) Сантиметровые волны, 3—30 *Ггц*	(4) Миллиметровые волны, 30—40 *Ггц*
151—154 (р)	400,05—406; 1660—1700	—	—
30—41; (4a) 41—47 (в); 68—74,8 (кроме вп); 75,2—87,5 (кроме вп): 100—108 (кроме R): 13[illegible]—137; 146—149,9 (кроме R); 150,05—156 (кроме R); 156—174 (5) (кроме вп); (4a) 223—235 (в); 235—300	300—328,6; 335,4—399,9 (5) 401—406; (в, кроме вп); 406—430 (кроме вп) (6) 450—470; 1350—1400; (5) 1427—1535 (кроме вп); (5) 1670—1690 (кроме вп); 1690—1700 (в, кроме вп); (5) 1700—2450 (в); 2450—2690	3,4—3,6; 3,6—4,2 (в); 4,4—5; 5,85—7,25; 7,3—7,975; 8,025—8,5; 10,5—10,68; 10,7—11,7; (5) 11,7—12,7 (кроме вп); 12,7—13,25; 14,4—15,25; 17,7—19,3; 19,4—21; 22—23; 25,25—30	30—31,3; 31,5—31,8 (в); 36—40
—	—	—	—
—	—	—	—
(4a) 37,75—38,25 (в);	1400—1427; (4a) 1664,4—1668,4 (в); 2690—2700	4,99—5; 10,68—10,7; 15,35—15,4; 19,3—19,4 (4a)	31,3—31,5; 33—33,4
30,005—30,01; 136—138; 143,6—143,65;	400,05—401; 1700—1710; 2290—2300	5,25—5,255 (в); 5,67—5,725 (в); 8,4—8,5; (4a) 15,25—15,35	(4a) 31—31,3 (в); (4a) 31,5—31,8; 31,8—32,3 (в); 34,2—35,2
30,005—30,01; (4a) 137—138; 267—272 (в); 272—273	401—402; 1427—1429; 1525—1540	—	—
—	—	(6) Для передачи со спутника: 3,4—4,2; 7,25—7,75; (7) с Земли: 4,4—4,7; 5,725—6,425; 7,9—8,4	—
149,9—150,05; 399,9—400,05	—	14,3—14,4	—
137—138	400,05—401; (4a) 460—470 (в); 1660—1670; 1690—1700; (4a) 1770—1790 (в)	—	—

Key: (1). Ultrashort waves, 30-300 MHz. (2). Decimeter waves, 300-3000 MHz. (3). Microwaves, 3-30 GHz. (4). Millimeter waves, 30-40 GHz. (4a). v. (5). besides VP. (6). For transmission from satellite. (7). from Earth.

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Let us note also general rule, according to which it is forbidden to establish/install and to utilize broadcasting service (sonic broadcasting and television) on board marine and airships or units, which float or which fly out of national territories. This rule does not relate to the communication satellites, for which must be manufactured special agreement.

For evaluation/estimate of employment of separate ranges of radio frequencies different radio services in Table 1.5 gave allocation of frequencies between 10 kHz and 40 GHz for region 1. Letter "r" (after the indication of frequency) corresponds to the permitted service, letter "v" - secondary [7, 8].

Air movable service is divided into two categories: R and OR. In category R is placed the radio communication service between airships and by those stations of the air service, which are intended for guaranteeing of safety and regularity of flights on the internal or international lines (routes). To category OR - radio communication service between the airships and the stations of air service, the ensuring safety of nonscheduled flights within the country.

Determination of remaining services, indicated Table 1.5, gives in "Regulations of radio communication".

1.4.2. Permanent elements of MSE.

General secretariat of MSE is obligated to publish following official documents [13]:

1. International list of frequencies - information about assigned frequencies, carried into the Reference international register of frequencies.

2. List of fixed/recorded stations, which work on international lines (their frequency they are indicated in international list of frequencies).

3. List of broadcasting service, which work at frequencies in bands is below 26100 kHz.

4. List of coast stations.

5. List of shipboard stations, equipped with radiotelegraph or radio-telephone equipment, with application/appendix of table and chart, that indicate zones and hours of work of radio services.

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6. List of stations of radio-determination and stations of special service. The firsts include direction-finding and radio-beacon stations; service of marine radio navigation; radio beacons of service of air radio navigation, suitable for marine

navigation, etc. The second include the stations, which transmit time signals, periodic weather messages, medical councils, standard frequencies, epidemiological bulletins, etc.

7. Alphabetical list of call signals, appropriated to stations, included in lists, enumerated in pp. 1-6.

8. List of stations of international control/checking.

9. chart of coast stations.

10. Colored table, which indicates appropriation of frequencies, enumerated in "frequency- allocation table between 10 kHz and 40 GHz".

General secretariat of MSE must regularly publish changes to enumerated documents on the basis of monthly notices of administrations of countries, which participate in distribution, about occured in them changes in parameters, which compose content of lists. The new publications of the "International list of frequencies" must be published not less than once a two years. List is quarterly supplemented by the compound supplements, which contain new records and changes, already introduced into the "International list of frequencies", and also the records, completely withdrawn from it. Remaining lists it is also regular, through the specific periods, they must be republished and be supplemented by newest data with the aid of the compound supplements (through each three or six months or within other periods on the solution of secretary general).

International committee of recording frequencies (MKRCh) is included in international union of electrical communication. For fulfilling their work the members of committee are gathered, as a rule, not less than once a week. Its current work is fulfilled by the secretariat, which consists of the highly skilled specialists.

Documents of MKRCh are comprised in French, English and Spanish languages.

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These three languages, and Russian and Chinese are also official languages of MSE.

In responsibility MKRCh enters:

1) examination of claims from countries for inclusion in "reference international register of frequencies" and its refinement;

2) examination and agreement of seasonal schedules of radio broadcasting at high frequencies;

3) composition and publication of lists of frequencies (on the basis of data of "Reference international register of frequencies");

4) study of use of radio frequencies for composition of recommendations regarding rational distribution of radio frequencies;

5) rendering to individual countries of necessary aid in questions of economical utilization of radio frequencies;

6) emission of cases of effect of interferences on radio equipment and composition of necessary recommendations;

7) preparation for conferences of radio communication and participation in national conferences and conferences on questions of distribution and use of frequencies.

About any appropriation of frequencies it is communicated in MKRCh, if equipment at this frequency can create inadmissible interferences with any service of other country. The claims are not sent to the series/row of frequencies (international frequencies of calamity, etc.). If conclusion of MKRCh is positive, the appropriation of frequencies is written/recorded in the Reference international register of frequencies and it uses the right/law of international protection from the interferences.

International consultative committee on radio (MKKR [International Radio Consultative Committee]) deals with examination of technical problems, connected with normalization of parameters of different radio systems. It regularly is assembled for discussion and making of decisions (as a rule, every three years).

MKKR consists of 11 research boards, which study different technical and operating questions of radio communication and prepare for recommendations, whose fulfillment contributes to decrease of interference level between different radio aids. The observance of these recommendations is not necessary during the development of different radio systems of radio communication, utilized in the limits of the individual country.

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However, if we do not adhere to them, then, on one hand, it is not possible it will be utilize this system on the international scale and, on the other hand, interferences between the radio-electronic means of different countries can be created.

Let us pause at short characteristic of research boards, whose new structure is accepted by XII plenary assembly of MKKR during January - February of 1970 in New Delhi (India) [15].

I. The research board of MKKR (use of the spectrum, control/checking) studies together with other research boards questions of the effective use of a radio spectrum, including of problem of the coincidence of frequencies taking into account the parameters of radio transmitters, radio receivers, antennas, etc. She also studies the principles of the classification of radio emissions, the methods of measuring the parameters of radio emissions at a distance, the employment of the spectrum and develops/processes the methods of measuring the radiation characteristics.

II. Research board (Services of space investigations and radio astronomy) deals with questions of connection/communication for the investigations in outer space and with questions, which relate to the decrease of interferences for the service of radio astronomy.

III. The research board (fixed/recorded services, which work at frequencies of below 30 MHz) examines the questions, which relate to the systems of communications of the fixed/recorded services at frequencies of below 30 MHz (with exception of radio relay lines), and also to the systems of ionospheric scattering.

IV. Research board (fixed/recorded services, which use satellites) examines characteristics of the systems of the connection/communication of the fixed/recorded services, which use satellites, including questions of tracking, telemetry and remote control.

V. Research board (Propagation in the nonionized medium) studies radiowave propagation (including radio noise) on the surface of the Earth through the nonionized regions of the earth's atmosphere, and also in the space, where the effect of ionization it is insignificant, for the purpose of an improvement in the radio communication.

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VI. Research board (Ionospheric propagation) studies radiowave propagation (including noise) in the ionosphere for the purpose of an improvement in the radio communication.

VII. Research board (Services of standard frequencies and time signals) coordinates questions of the transmission of standard frequencies and time signals.

VIII. Research board (Movable services) deals with the technical and operating questions, which relate to by air and marine movable, land-based movable services and to the service of radio determination, and also to the use of satellites.

IX. Research board (fixed/recorded services, which use radio relay systems) deals with the questions, connected with radio-relay lines of sight and the tropospheric radio relay lines, which work at frequencies of higher than 30 MHz.

X. Research board (Service of radio broadcasting) investigates the technical aspects of radio broadcasting among other things with the aid of ISZ in the together utilized bands of frequencies, etc.

IX. Research board (Service of television) investigates the technical aspects of radio broadcasting among other things with the aid of ISZ in the together utilized bands of frequencies, etc.

United research board MKKR/MKKTT [1] (for television and sonic transmissions) together with research boards of MKKR and MKKTT [International Telegraph and Telephone Consultative Committee] studies characteristics of systems of long-distance communication, by which are transmitted programs of sonic broadcasting and televsion up to large distances.

FOOTNOTE MKKTT - International consultative committee on telegraphy and telephony. ENDFOOTNOTE.

United research board MKKR/MKKTT (on dictionary) must emit together with other Research Boards of MKKR and MKKTT technical terminology and other questions (graphic and literal symbols, etc.).

1.4.3. Latter/last international radio-conferences.

In 1963 in Geneva and in 1966 to Oslo passed work of X and XI plenary assemblies of MKKR respectively.

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The documents of assemblies are of great interest therefore are wholly translated into the Russian language [16-19]. Let us pause briefly at the content of these materials. Among them - different recommendations, reports about the made work, questions, which require investigations, research programs, etc.

First volume is dedicated to questions of emission, reception/procedure and terminology. In it they are brought the classification of the bands of frequencies (it it is repeated in all volumes) and terminology in the field of emissions and their reception/procedure, are given relationships/ratios between the peak power, with average/mean power they are illuminated are questions of the measurement of spectra and width of the emission band, supplementary emissions, possibility of decreasing interferences, questions of frequency fixing of transmitters, is examined the determination of maximum interference level from the industrial, scientific and medical installations, and also from other forms of electrical apparatuses, etc.

In second volume, dedicated to questions of radiowave propagation, are given propagation curves for frequencies of below 10 MHz, and also for frequency band from 40 to 1000 MHz, necessary during solution of question of distribution of radio frequencies for broadcast and movable services and during determination of minimum territorial separations taking into account interferences due to tropospheric scattering. Considerable place is assigned to materials about the field strength; about density measurements of the power flux, radiated power; about the data on the radiowave propagation, necessary for the radio relay systems; about the curves of tropospheric propagation for the evaluation/estimate of interferences in the range 1-10 GHz, etc.

In third volume are examined fixed/recorded and movable services, standard frequencies, time signals and control of emissions (questions of decrease of occupied width of band and power, shielding relations signal/noise, separation of channels concerning frequency, materials about interferences, etc.).

To radio relay systems, to space systems and radio astronomy is diverted fourth volume. In it are given diverse materials, connected with allocation of frequencies for the radio relay lines of sight and for the tropospheric radio relay systems.

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Let us note that due to the large power of transmitters (1-10 kW) and antenna gain, equal to 40-50 dB in the main direction, the tropospheric systems can create the inadmissible interferences at large distances (to 1000 km). This forced MKKR to recommend during gliding/planning of tropospheric radio relay systems to realize the necessary international coordination actions, which, besides the account of interferences, created with the joint operation of troposphere systems, the radio relay lines of straight/direct visibility and other services, which work in the same frequency bands. Simultaneously with this, thoroughly planning the distribution of radio frequencies, should be taken the measures, which facilitate the decrease of the radiated power of tropospheric systems up to the reasonable limit and the decrease of both the emission, and of the possibility of reception/procedure in the undesirable directions, and also a maximally possible decrease of spurious radiations.

In fourth volume are given materials, which relate to space systems and radio astronomy: selection of frequencies, utilized for connection/communication with artificial satellites, between them, and also with other spacecraft; identification of radio emissions of spacecraft; discontinuance of radio emissions from spacecraft; possibility of combined use of frequency bands from 1 to 10 GHz with nonspace radio communication services; maximum permissible sound levels in telephone channel of radio relay system; maximum permissible values of density of power flux, created on surface of Earth by communication satellites; determination of three-dimensional/space separation (coordination distance), which prevents interferences between terrestrial stations and ground stations of nonspace services, which together use frequency bands; criterion for selection of preferable relative frequencies for communication systems with the aid of satellites, which use frequency bands together with radio relay systems of straight/direct visibility; requirement for frequencies milking of radio-navigation systems with use of satellites; the frequency band for the meteorological satellites, for the means of telemetry, tracking and remote control, utilized on the developed/processed and exploited satellites; frequency, width of bands and norm of interferences for the lines of communications, which use the low- flying satellites, for the lines of communications in deep space (i.e. in outer space at a distance from the Earth, approximately equal or greater than distance from the Earth - to the Moon), for research manned spacecraft; the frequency band for the connection/communication with the spacecraft with the entry into the dense layers of the Earth's atmosphere; the protection of frequencies, utilized for the radio-astronomical measurements, from the interferences; the factors, which affect the possibility of the combined use of frequency bands by the service of radar astronomy with other services, etc.

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In the fifth volume are published materials, dedicated to radio broadcasting and television (frequency separations, protection from interferences, etc.).

Separate volume [17] published materials about distribution of atmospherics on terrestial globe and about their characteristics.

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2. ELECTROMAGNETIC SITUATION IN THE RADIO- ELECTRONIC COMPLEXES AND THE PARAMETERS of EMS.

Electromagnetic situation, in which function RES, these are totality of electromagnetic radiations, which affect RES, created with other RES, electrical devices/equipment and sources of natural origin. It is determined by many factors, among which essential are the number and the power of the emitters of radio interferences and the spectra of their emissions. For the evaluation/estimate of electromagnetic situation and determination of the methods of fight with the interferences it is important to know, on what devices/equipment RES of interference act: antenna-feeder circuit, feed circuits, switching circuits and directly to the elements of RES.

In practice electromagnetic situation is evaluated both for group RES, united at system of specific designation/purpose (receiving center of remote KV of radio communication, point/item of tracking for ISZ, complex of radio equipment on ship, aircraft, etc.) and for individual radio aid (receiver of radar, broadcast receiver, etc.).

For describing electromagnetic situation there is no single method. In the general case it is possible to distinguish the electromagnetic situation as:

- external with respect to the system RES (or to the individual equipment), divided three-dimensional/space from other systems;

- internal with respect to the component parts of the complex RES, united into the system in the limits of the limited space.

In first case is evaluated totality of electromagnetic radiations from many one or sources, which are located on sufficiently large distances (remote zone of emission), and the secondly - at short distances at (sometimes near zone of emission, when distance from source of interferences less $\lambda/2\pi$). Interferences in the first case affect through the antenna circuit, and the secondly they can affect along all possible paths.

Analysis of external electromagnetic situation is carried out experimentally and theoretically by determining charging operating frequencies, determination of sources of interferences (among other things of irregular), measurement of parameters RES, which affect EMS, calculation of probable interference level according to fundamental and nonbasic/minority channels of reception/procedure (see Chapter 7), simulation of electromagnetic situation, etc. The knowledge of the electromagnetic situation is especially important when the level of useful signal is small so, that it borders on ultimate sensitivity of reception/procedure. According to the results of analysis it is expedient to create charts of possible interferences, intended as for forecasting the interferences, it flowed also for the adjustment of the conditions of three-dimensional/space or temporary/time, and in the series/row of the cases and frequency separation between RES of this system and interfering RES.

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The continuously increasing charging of radio-frequency ranges leads to the fact that emission of external electromagnetic situation becomes ever more and are more necessary. For example, for RES of meter range, which work in the large industrial centers, it is important to know the level of the general/common background of man-made interferences. This background is measured far from concentrated sources of interferences by the equipment, established/installed on the aircraft (helicopters). The results of measurements show the presence of the essential interference level in the large cities, which can affect the conditions of the reception of information from the satellites in reception points, placed near such cities, for example.

Internal electromagnetic situation in radio systems, whose component parts contain sufficiently powerful transmitters and sensitive receivers of different designations/purposes, frequently proves to be very complicated. In such systems the sources of interferences prove to be in immediate proximity of the devices/equipment, which receive interferences, which leads to the need for the analysis of the numerous ways of forming the interferences. Thus, for instance, interferences can be created with nonbasic/minority emissions of the transmitters, whose frequency is close or corresponds to the frequency of the nonbasic/minority channels of the reception/procedure of the receivers of complex.

Emissions, which are radio interferences for concrete/specific receiving device RES, in general form are random functions of time [1-3]. In a general case during the evaluation of the electromagnetic situation in the elaborate radio-electronic complexes it is necessary to consider:

- levels and the spectra of the main and minor emissions of the transmitters of the complex and of other transmitters, whose action is possible on the receivers of complex, and also emission of the heterodynes of receivers;

- sensitivity of receivers along the fundamental and nonbasic/minority channels of reception/procedure and permitted signal/noise ratio at input, with which the normal for the work of end devices signals, which carry useful information, are provided;

- overload receiver responses, which determine the properties of the latter to accept useful signal in the presence of the stronger interfering signal with the frequency out of the working passband of receiver according to the intermediate frequency;

- coupling coefficient between the closely spaced antennas of systems, created and accepting interferences in this complex radio aids.

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In order during design of radio systems to forecast probable interference levels and to develop/process measures, which ensure EMS, it is necessary to know factors, which determine electromagnetic situation of RES, and among other things parameters RES, which affect their EMS. With the following presentation for the brevity of the designation of these factors we will utilize a term the "parameters EMS", implying in this case, that they have (or they can have) the quantitative estimations, suitable for the practical comparison of separate types of RES on from to properties to work together and simultaneously with other RES and different electrical devices/equipment.

Among parameters they are radio-electronic devices/equipment it is possible to isolate group, which has value not only for guaranteeing EMS, but also more general/common value for characteristic of properties of these devices/equipment. These parameters determine energy potentials of the transmitting devices during the fundamental emissions and noise immunity of receiving devices on the fundamental channels of reception/procedure and make it possible to rate/estimate the level of radio interferences with the work of RES at the together utilized or closely spaced frequencies. To such parameters relate:

- operating frequency;
- power of fundamental radiation of transmitter;
- bandwidth of the fundamental emission of transmitter;
- parameters of control of the high-frequency oscillations (depth of AM, the value of deviation, the pulse duration, porosity, etc.);
- sensitivity of radio receiver at the operating frequency;

- selectivity of radio receiver - frequency, connected with the passband of receiver, amplitude, that makes it possible to isolate signals in the dependence on their level, temporary/time, that eliminates the action of interferences in the intervals between signals, etc.;

- minimally permissible relation signal/noise at the input of concrete/specific type of receiver;

- frequency stability of radio link, transmitter and receiver;

- radiation pattern and antenna gain at the operating frequency.

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To second group of parameters, which have value mainly for determining EMS, can be attributed:

- levels of nonbasic/minority emissions of transmitter, i.e., emissions on harmonics and subharmonics, and also of combination, parasitic, out-of-band, noise and intermodulation emissions;

- sensitivity of receiver on each nonbasic/minority channel of reception of interfering signals; existence of such channels of reception/procedure depends on nonlinear properties of converters of frequency and high-frequency amplifiers of superheterodyne receiver; such channels include intermodulation channels of reception/procedure, caused by simultaneous effect of two or several interfering signals on receiving device;

- selectivity of receiver along adjacent channel (adjacent channels) of reception/procedure, evaluated by two-signal or multi-signal method and which characterizes property of receiver to filter out undesirable (interfering) signal in adjacent channel (adjacent channels) in presence of desirable signal in fundamental channel of reception/procedure; this property is defined by both the parameters of the tuned oscillatory circuits of receiver and by nonlinearity of volt-ampere characteristics of its electric vacuum (or semiconductor) devices, and can be qualitatively evaluated by the coefficient of the blocking of reception/procedure and by the coefficient of crosstalk of useful signal; these coefficients characterize the action of the interfering signal of of stronger than useful, with the frequency of the outside working passband of receiver;

- radiation pattern and the factors of amplification of the transmitting antennas at frequencies of nonbasic/minority emissions, and also receiving antennas on the nonbasic/minority channels of reception/procedure;

- value of crosstalk attenuation (coefficient of decoupling) between the transmitting and receiving antennas, placed in a sufficient nearness, that characterizes the relation of the power of the signal, perceived by one antenna, and the power of the same signal, which enters another (transmitting) antenna;

- stress level, caused by man-made interferences, in the feed circuits and commutation of RES;

- the coefficients of the effectiveness of the shadowing of assemblies, blocks and apparatuses, characterizing the degree of weakening electromagnetic field at frequencies of fundamental and nonbasic/minority emissions of RES, which is propagated besides the antenna circuit, and also the degree of protection of RES and their elements from this electromagnetic field;

- coefficients of the effectiveness of metallization and grounding/ground.

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Besides enumerated parameters on electromagnetic situation, in which, work RES, they can have effect series/row of other factors, not connected with RES directly. It is possible to note among them:

- level of the field, created with the sources of man-made interferences;

- level of the field, created with the inadequate electrical contacts in the mechanical connections of metal constructions, which are located in the field of powerful emitter (interference level from the irradiated contacts).

Enumerated factors, in more detail examined/considered in subsequent chapters, it is possible to consider it fundamental for evaluation of electromagnetic situation of RES. Some of such factors or parameters can be determined quantitatively in the form of the permissible norms as, for example, norms to the man-made interferences. Other parameters do not have a quantitative estimation and a norm on them they require even supplementary investigations. To such parameters, for example, relate the coefficients of gain of the antenna radiation pattern on the harmonics of transmitters, the coefficients of the effectiveness of metallization and groundings/grounds, which affect the levels of spurious coupling between the elements of radio-electronic complexes, and the series/row of others.

Furthermore, electromagnetic situation depends on three-dimensional/space, frequency and temporary/time separation of RES, i.e., from organizational and technical working conditions for their. Such conditions affect:

- probable levels of the strength of the field (density of power flux) of useful and interfering signals and respectively to the selection of the frequencies of these signals;

- probable limits of a change in the losses of useful and interfering signals during their propagation from the place of origin to the receiving device;

- probability of coinciding the time of the reception of useful and interfering signals.

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Given enumeration of parameters of EMS characterizes complexity of problem of guarantee of simultaneous and joint operation of RES. Is especially complicated resolution of this problem in the radio-electronic complexes, whose elements are placed in immediate proximity, that it is possible to illustrate in a number of examples.

Aboard contemporary warship is utilized several ten radiotransmitter and radio receiving equipment of different designation/purpose, many of which work in close to each other wave bands [1, 4]. For the work of these devices/equipment on the ship with an area on the order of 150×15 m^2 are necessary to establish/install about forty antennas, between which it is not possible to ensure the necessary "decoupling". In the radiolink systems to one mast they establish/install several antennas, and also is used one wide-band antenna for several simultaneously working transmitters. The reliable decoupling between the transmitters with the aid of the special filters is necessary to avoid intermodulation emissions in such systems.

In similar complexes sharply complicated is work of receivers, since at their inputs interfering signals with level of order of several ten volts can appear. As a result of the close arrangement/position of RLS of large power their wide-band pulse signals create considerable radio interferences in the receivers of other systems. Harmonics and combination emissions of transmitters are also the sources of the radio interferences of high level. The simultaneous work of several transmitters can lead to the appearance of radio interferences of intermodulation character.

Interesting illustration of complexity of guaranteeing EMS can serve radio-electronic complex of oceanic ship, utilized as point/item of tracking, connections/communications and administrations of satellite of type "Apollo".

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Besides regular radio communications KV and VHF equipment, system of the determination of the coordinates of ship, including of inertial navigation system, and of system of the operational control of the work of shipboard control instruments, on ship is placed the following special equipment:

- system of single time;

- system of data acquisition about the coordinates of satellite, connected with the electronic device of control of tracking antennas and of their stabilization;

- system of the medical checking of the state of cosmonauts;

- system of tracking the satellite with the aid of RLS with the transmitter with a power of 1 MW and the parabolic antenna with the diameter of 5 m (range 5.4-5.8 GHz);

- the standardized system of tracking the satellite, the determination of its range and radio communication with it, that contains the transmitter with a power of 20 kW (range 2.0-2.2 antenna);

- system of command control with the transmitter the power of 10 kW and by spiral antenna (range 400-500 MHz);

- system of telemetering reception in three ranges (105-140 MHz, 216-260 MHz, 2.2-2.3 GHz) with the receivers by sensitivity - 127 dB/W and by two receiving antennas, one of which tracking, parabolic type by the diameter of S.1 m works in two latter from the ranges indicated;

- system KV and DMV of radio communication for the transmission on real time of telemetric data, obtained from the satellite, to the control center of control of space flight; provides telephone and telegraph communication in the directions ship - coast, ship - satellite and ship - ship; it contains six transmitters with a power of 10 kW each (range 2-20 MHz), eight high-stability receivers (range 2-30 MHz), four KV receivers of the general purpose and four DMV of radio station with the transmitters with a power of 100 W each; in the system two log-periodic antennas and three spiral are utilized.

Guarantee of EMS of enumerated systems required great work on determination of sources of interferences and decrease in their level.

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Especially strong interferences were created by powerful/thick KV by the transmitters, with work of which the field strength, for example, at a distance of 7.5 m from spiral DMV of antenna reached 200 V/m. During such powerful/thick emissions for the protection of receivers it was necessary to use special filters in the antenna feeder circuits. Furthermore, it was necessary to create special protection for the receiver of RLS, the wide-band circuit of intermediate frequency of which was tuned on 30 MHz. From the powerful/thick emissions it was necessary to shield even elements of power supplies. Thus, for instance, emissions KV of transmitters saturated silicon diode in the stabilization assembly of the filament circuit of the klystron of receiver, which deranged in the absence of the devices/equipment of protection.

Besides interferences from transmitters appeared interferences, also, from other sources. For example, the emissions of the heterodyne of the receiver of the standardized system of tracking and connection/communication (range 2.0-2.2 GHz) created interferences with telemetric receiver.

Considerable radio interferences from irradiated contacts were discovered in stage of introduction of described complex to operation. The source of such interferences, for example, proved to be the circuit of onboard enclosure/protection, whose components/links, irradiated by field powerful/thick KV of transmitter, had variable/alternating contacts with each other, in consequence of which were created the radio interferences and wide frequency band, including range 2.0-2.2 GHz. Noise level at the input of telemetric receiver in this case was raised on 20-30 dB. The sources of interferences from the irradiated contacts proved to be also rotating mechanism of telemetric antenna, which plays between the gears, variable/alternating contacts in the loops of doors, hatches and suspended tubes, unreliable contacts at ground points of the shielding braid/cover of cables, etc. For dealing with the radio interferences from the irradiated contacts were used different measures: the ground of loops by flexible busbars, the installation of the contact brushes on the gears of the antenna mechanism, the replacement of the physical circuits of enclosure/protection by rope from the synthetic material, an improvement in grounding the screens/shields of cables, etc.

Analogous problems of EMS appear also in simpler radio-electronic complexes, which equipped, for example, marine transport and trade vessels.

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For the evaluation of the possible sources of radio interferences let us enumerate the characteristics of some RES, utilized on these vessels [5-7]:

- means of radar scan on the wave 3.2 cm with a pulse power of transmitter of 80 and 100 kW; the sensitivity of receivers is -110-120 dBW;

- receiving devices of radio-navigation systems (radio direction finders), intended for the pilotage on the sector beacons VRM-5 and "KONSOL" (range 186-750 kHz), on the signals of phase and radio-navigation system "Decca" (range 70-140 kHz) and pulse radio-navigation system "Loran-A" (range of approximately 2 MHz); the sensitivities of receivers are equal to 3-10 μV;

- main radio communication equipment - transmitters of the medium-frequency waves with a power of 250-300 W and the receivers of long and medium-frequency waves;

- operating radio communication equipment - transmitters with the range 1.5-24 MHz and an average/mean power of up to 400 W or combined the transmitters of average/mean and short waves and receivers with the range 12-25000 kHz;

- emergency radio communication equipment - transmitters of the medium-frequency waves with a power of 25-60 W and the corresponding receivers, including for the automatic reception of international alarm signal at the frequency of 500 kHz (auto-alarms); the same means include the boat radio stations, which work on the fixed/recorded marking waves of anxiety and calamity;

- common radio communication equipment - transceivers, which work on the intermediate and ultra short waves, for the connection/communication in the limited coastal areas and on the raids; such means include the radio stations (156-162 MHz) with an average/mean power of up to 10 W, pilot radio stations (156.3-156.8 MHz), etc.;

- command-broadcast means with the possibility of the relaying of broadcast programs.

Combined use of enumerated means requires large number of antennas, which it is necessary to place on one mast or between masts at small distances from each other. When simultaneous work of RES is necessary, in the shipboard radio equipment can appear the interferences.

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Thus, for instance, without carrying out detailed analysis, it should be noted that the harmonics of SV and KV transmitters, through the antenna can create interferences of KV receivers, but the harmonic of the high orders (from the seventh and above) of the same transmitters - to VHF receivers. Harmonics and fundamental emissions of the same transmitters can fall into the receivers along their supplementary channels, including along second channel, whose sensitivity on 60 dB lower than sensitivity of fundamental channel. For weakening of the emission of transmitters on the harmonics the low-pass filters, switched on between the output of transmitter and antenna, must be utilized. For reduction in the interferences, which affect RES on the feed circuits and commutation, mounting of the cables of these circuits it is realized in accordance with the "Rules of Register of the USSR for electrical equipment of marine vessels". The observance of technical operation instructions of shipboard radio navigation instruments and radio communication equipment also contributes to the decrease of interferences.

The same special features of electromagnetic situation are characteristic for complex of aircraft equipment, in which must be provided simultaneous and joint operation of radio systems of different designation/purpose. They include, for example, systems [10]:

- remote radio communication on KV;
- near radio communication on VHF;
- long-range navigation on DV and SV;
- short-range navigation on VHF;
- airborne radars on SMV (or DMV);
- altimeter on VHF;
- identification;
- telemetry;

- crew intercommunication equipment, etc.

During practical final adjustment of radio complex as single whole considerable difficulties appear, even if separate systems correspond to requirements of EMS.

Rational arrangement/position on the aircraft of the numerous antennas, which must have minimally permissible coupling coefficients with the friend, is one of the complex problems. The degree of the decoupling between the antennas depends on the design features of each antenna and conditions for its arrangement/position, which affect the radiation pattern and the polarization of emission.

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In the general case an increase of the decoupling between the antennas, mounted on the total metallic surface, is determined by absorption, phasing and reflection of emitted energy [9].

Another complex problem is correct mounting of cables of diverse designation/purpose, which can be conductors of radio interferences. Numerous cables are laid in the cockpit, in which are placed the control panels, by radio systems. The large number of cables is utilized into the qualities of intermodule connections, supply leads, feeder systems, switching circuits of crew intercommunication equipment, etc. Almost all these cables for purposes of protection from the penetration of interferences must have special filters.

Cables must be thoroughly shielded and grounded. The cables, which relate to the systems, which create and which receive radio interferences, must be distant from each other or laid at the right angle to each other. In the practice of the mounting of aircraft equipment are known the cases of the creation of the interferences, which were being propagated along the cable system, from the radio navigation locator in the circuit of radio compass, KV and VHF communication receivers and the receiver of system "Loran".

Sources of interferences in aircraft equipment can be also numerous electromechanical devices/equipment - servomotors, relays, control gears, etc. Due to the insufficient shadowing of powerful/thick pulse modulator of RLS with its work can appear direct "inductions" to the blocks of other radio systems. In the literature it is also noted that the radio interferences are created by the onboard devices/equipment, which work in the pulsed operation and which cause the transient processes (the "surges of voltage/stress") in the onboard electrical system of direct current [11].

Given examples of electromagnetic situation make it possible to conclude that careful analysis of possible sources and paths of propagation of interferences is necessary during layout of radio-electronic complexes. In the series/row of cases the electromagnetic situation can be simulated for determining of possible levels and frequencies of the interfering signals. In all cases of RES, intended for the work in the complex with other RES, they must be developed/processed taking into account their parameters, which determine EMS.

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6. NORMS AND THE RECOMMENDATIONS, DIRECTED TOWARD THE LIMITATION OF THE LEVEL OF RADIO INTERFERENCES.

For guaranteeing electromagnetic compatibility they are developed, are developed/processed and will be developed/processed recommendations or norms, directed toward limitation of level of radio interferences both within country, and on international scale. Now it is not yet clear, should be normalized all without the exception/elimination parameters of electromagnetic compatibility. Serious investigations in this direction yet it was not carried out. There is no yet and strict proof about the sequence, in which it is necessary to carry out a similar normalization. Let us note that the already prepared norms are necessary for all ministries and departments, which develop/process, which release, which acquire on the import and which operate the radio-electronic means of all designations/purposes and electrical and other devices/equipment, which are the source of industrial radio interferences.

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The fulfillment of the norms and other limitations, which pursue the same targets, is monitored by the services of technical radio control, also, at the transmitting radio centers. The reports of different ministries and departments, accepted are corresponding solutions and the necessary organizational and technical actions are realized. Is checked the fulfillment by the radio stations of the commercial standards of radio emissions, including on frequency stability, the rules of the use of radio frequencies, the conformity working industrial, medical and scientific radio-frequency installations to the norms of permissible industrial radio interferences, etc. Are accepted also the solutions about the protection of the separate frequency bands from the interferences, created by other radio services, which work in these bands, about the study of the radiowave propagation of different ranges, about the development of the optimal technical-economic solutions, which facilitate the decrease of the level of industrial radio interferences in the USSR cities, etc.

6.1. NORMS TO THE BANDWIDTH FOR DIFFERENT CLASSES OF EMISSIONS.

Bandwidth, occupied during emissions by radio-electronic means, is one of most important parameters, on which depends EMS, also, in the final analysis economical utilization of radio-frequency spectrum. Therefore after conducting of the number of investigations in 1961 temporary/time all-Union norms to the width of emission band in the various forms of modulation were developed. The concrete/specific technical solutions, directed toward the limitation of the width of emission band and toward further investigations in this region, were accepted. Taking into account these norms with development and production of radio transmitters.

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This made it possible to develop and in 1966 to affirm "All-Union norms to the bandwidth for different classes of the emissions (for radio transmitters of civil designation)", which apply to the radio equipment of different designation/purpose, which uses amplitude, frequency and pulse modulations [1]. Norm to the width of emission band will be now introduced into the technical assignments for all developed/processed radio transmitters in the range of the kilometer, hectometer, decametric and ultrashort waves (for the part of the radio-electronic means of norm to the width of emission band are not yet developed). Only the application of the most effective forms of modulation, which ensure the minimally necessary frequency band, the optimization of the deviation of frequency for ChM of emissions, the maximum use of mode of one sideband, etc., will make it possible to fulfill new norms.

It should be noted that in norms indicated are given recommendations regarding limitation of spectra of out-of-band emission, which present part of energy radiation spectrum (with exception of spurious radiations at frequencies, far distant behind boundaries of necessary band), which is located out of necessary band and is source of interferences.

It is necessary to emphasize also that norms are given to necessary and to occupied bandwidth, moreover the second differs from the first by appropriate correction [7]. The presence of correction is caused by the fact that, for example, in the transmitters of the classes of emission A3, A3A, A3H and A3J it is extremely difficult to obtain width of occupied band of frequencies, equal to the necessary width, since it is not possible to attain the ideally steep fronts (ramps) in the filters, which determine width of necessary band, i.e., it is not possible to obtain the factor of form (ratio of passband at any level to the stipulated passband), equal to 1. But this means that the out-of-band power of transmitter will comprise more than 0.5% of entire average/mean power of this radiation, i.e., width of occupied band of frequencies will be more than the necessary bandwidth. Therefore tolerances for the occupied bandwidth for the classes of emissions A3, A3A, A3H, A3J and A3B are assigned in accordance with the available recommendations of MKKR to the rate of the decrease of the spectra of out-of-band emissions in the dependence on the value of the zero and measuring levels, at which should be measured the bandwidth during the checking to the conformity to norms. As can be seen from Fig. 6.1, for the class of emission A3J the measured bandwidth $B_{\text{н}1}$ (or $B_{\text{н}2}$) depends on measuring level $b_{\text{н}1}$ (or $b_{\text{н}2}$) selected with respect to the zero level.

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Tolerances for classes of emissions A1, A2, A4, F1, F3, F4 and F6 are determined from other considerations. The radiation spectra of these classes during the transmission of periodic signals are discrete/digital, the frequency of spectral components is equal to modulation frequency. Consequently, and width of occupied band of frequencies must be the discrete variable, expressed in the whole even numbers of modulation frequency. But, since the necessary bandwidth depends also (linearly) from the deviation, the sub-carrier frequencies also of other parameters, which do not depend on modulation and, therefore, which are capable to be changed smoothly, then width of occupied band of the classes of emissions in general form indicated is expressed in the nonintegral values of modulation frequency.

6.1.1. Norms to necessary width of band B_n

Let us give formulas, from which it is possible to design norms for B_n.

Amplitude modulation.

1. For single-channel telegraphy by sustained oscillations, A1:

$$B_n = KB,$$

where B - telegraph rate, baud; K=5 - for lines, subjected to fading; K=3 - for lines without fading (for different types of transmitters of value "K" they are established/installed in technical of permissible distortion of signal and range of utilized frequencies).

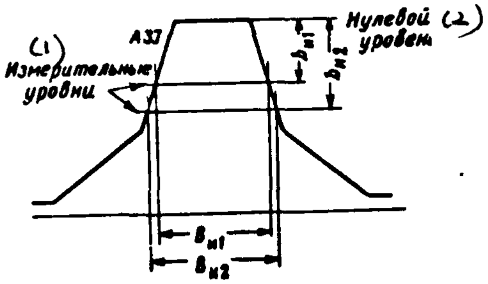

Fig. 6.1. Key: (1). Measuring levels. (2). Zero level.

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2. For tone telegraphy, A2:

$$B_{н}=2F_{в}+5B,$$

where $F_{в}$— maximum modulation frequency, Hz.

3. For radiotelephony with two sidebands, A3:

$$B_{н}=2F_{в}.$$

4. For radiotelephony with one sideband with complete or weakened carrier, A3N and A3A:

$$B_{н}=F_{в}.$$

5. For radiotelephony with one sideband with the suppressed carrier, A3J:

$$B_{н}=F_{в}—F_{н},$$

where $F_{н}$— minimum modulation frequency, Hz.

6. For radiotelephony with two independent sidebands, A3B:

$$B_{н}=2F_{в}.$$

7. For radio broadcasting, A3:

$$B_{н}=2F_{в}.$$

8. For radio broadcasting with one sideband with weakened carrier, A3A:

$$B_n = F_в.$$

9. In the facsimile connection/communication with the carrier modulation with the aid of frequency-modulated subcarrier, A4:

$$B_n = 2F_n + 1{,}5N,$$

where F_n — sub-carrier frequency, Hz; N - maximally possible number of white and black elements, transmitted per second, with the phototelegraphy.

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Frequency modulation.

1. For frequency telegraphy, F1:

$$B_n = 2{,}6D + 0{,}55B \text{ for } 1{,}5 < m < 5{,}5,$$

$$B_n = 2{,}1D + 1{,}9B \text{ for } 5{,}5 \leqslant m \leqslant 20,$$

where D - maximum deviation of frequency, Hz; $m = D/F_в = 2D/B$ — index of frequency modulation.

2. For commercial telephony, F3:

$$B_n = 2D + 2F_в.$$

3. For radio broadcasting F3 (monophonic channel)

$$B_n = 2D + 2F_в.$$

4. For stereophonic radio broadcasting, F3, B_n increases by 20% in comparison with monophonic radio broadcasting.

4. For facsimile connection/communication with frequency modulation of carrier of transmitter by photosignal in the form of pulses, F4:

$$B_n = 2D + 0{,}855N \text{ for } 0{,}14 \leqslant m < 0{,}77,$$
$$B_n = 2D + 1{,}23N \text{ for } 0{,}77 \leqslant m \leqslant 1{,}7,$$
$$B_n = 2D + 1{,}5N \text{ for } 1{,}7 < m \leqslant 3{,}45.$$

5. For two-channel frequency telegraphing (DChT), F6:

$B_n = 2{,}6D + 2{,}75B$ — for nonsynchronized channels,

$B_n = 2{,}2D + 2B$ — for synchronized channels.

Pulse modulation.

For unmodulated pulses, RO:

$$B_n = 2K/t,$$

where $1 \leq K \leq 10$ it depends on $\Delta\tau$ - relative time of establishment of pulses; t - pulse duration, s.

For modulated pulses, P2 or P3, norms at present are not yet developed.

Television.

Necessary bandwidth in black and white television (image transmission and sonic tracking, A5 and F3) is regulated by GOST [All-Union State Standard] 7845-55 and is $8 \cdot 10^6$ Hz: span of band of picture signals is equal to 7.625 MHz, width of emission band ChM of sonic tracking - 0.375 MHz.

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6.1.2. Norms to the occupied bandwidth $B_{зан}$

1. For emissions of classes A1 (with K=3), F1 (with m≤5), A4 and F4:

$$B_{зан}=B_n+F_m,$$

where $F_m=B/2$— frequency of manipulation, Hz.

2. For emissions of classes A1 (with K=5), F1 (with m>5), A2 and F6:

$$B_{зан}=B_n\pm 2F_m.$$

3. For the emissions of class F3 (with m≤5):

$$B_{зан}=B_n\pm F_m,$$

For emissions of class F3 (with m>5):

$$B_{зан}=B_n\pm 2F_m.$$

4. For the emissions of classes A3, A3A, A3B, A3H and A3J:

$$B_{зан}=B_n(1+\Delta B),$$

where ΔB - tolerance, equal to 0.4 - for all classes A3; for radiotelephony of classes A3A and A3H ΔB=0.15 (with $F_н=300$ Hz, $F_в=3400$ Hz), ΔB 0.18 (with $F_н=250$ Hz, $F_в=3000$ Hz); for radio broadcasting ΔB=0.18 ($F_н=50$ Hz, $F_в=8000$ Hz), for all classes A3J ΔB=0.3 and for all classes A3B ΔB=0.15.

6.2. Norms of frequency stability of the radio transmitters of all categories and designations/purposes.

With one of most important indices, which make it possible to ensure normal work of radio-electronic means and absence of interferences between separate types of radio equipment, is permissible amount of deflection of frequency of radio transmitters.

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If in some coherent-pulse radars relative instability of frequency of transmitters composes 10^{-8}-10^{-9}, in radio relay lines according to recommendations of MKKR this instability is equal to 10^{-4} (in frequency band from 100 to 500 MHz) and $3 \cdot 10^{-4}$ (in band 500-10500 MHz), then to series/row of other transmitters is characteristic great instability of frequency. For example, only temperature frequency drift of magnetron transmitter at the frequency of 10 GHz is 0.1-0.2 MHz on 1°C, and the overall value of the instability of the frequency of magnetrons from different factors at the frequency of 10 GHz reaches ±20 MHz. It is natural that the regulation also of this parameter is necessary.

In 1962 are established/installed strict norms on stability frequencies of transmitters [2], given in Table 6.1. They are expressed in the millionth portions or, in the stipulated cases, in hertz. The introduced in 1969 partial changes of the norms for the stations of marine movable service, fundamental from which - norm $300 \cdot 10^{-6}$, in Table 6.1 they did not enter.

During development of new radio equipment, intended for automated lines of communications, single-band systems of communications, systems of synchronous radio broadcasting and new systems of special-purpose service, must be provided frequency stability of order 10^{-7}-10^{-8} (depending on equipment usage).

6.3. Norms to the spurious radiations of the radio transmitters of all categories and designations/purposes [2].

Spurious radiations of radio transmitters, apparently, are most essential factor, which determines EMS. Therefore to the levels of spurious radiations, beginning with 1962, they began to establish/install the norms (latter/last norms for a considerable quantity of classes RES, accepted in 1968, here they are not examined). Are calibrated the power of spurious radiations, applied to the antenna or its equivalent, at the nominal power of transmitter at the fundamental frequency.

For newly developed/processed radio transmitters, which work at frequencies it is below 30 MHz, average/mean power of any spurious radiation $P_{доб\,ср}$, which enters feeder of antenna system, must be on 40 dB lower than average/mean power at fundamental frequency $P_{осн\,ср}$, but not more than 50 mW.

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Table 6.1.

(2) Категория радиостанций	(1) Стабильность частоты													
	(3) в полосе 10—535 кгц		(3) в полосе 535—1606 кгц	(3) в полосе 1606—4000 кгц		(3) в полосе 4—29,7 Мгц			(3) в полосе 29,7—100 Мгц		(3) в полосе 100—470 Мгц		(3) в полосе 470—10 500 Мгц	
(4) Фиксированные станции	(5) в полосе		—	(6) при мощности										
	10—50 кгц	50—535 кгц	—	≤200 вт (8)	>200 вт (8)	≤500 вт (8)		>500 вт (8)	≤200 вт (8)	>300 вт (8)	≤50 вт (8)	>50 вт (8)	≤100 вт (8)	>100 вт (8)
	1000 (7)	200 (7)	—	100	50	50		15	50	30	50	20	300	100
Наземные станции: (9)	(6) При мощности													
	≤200 вт (8)	>200 вт (8)		≤200 вт (8)	>200 вт (8)	≤500 вт (8)	500÷5000 вт (8)	>5000 вт (8)	≤15 вт (8)	>15 вт (8)	≤5 вт (8)	>5 вт (8)		
(10) береговые	500	200	—	100	50	50	30	15	50	20	20	20	300	
воздушных служб	100	100	—	100	50	100	50	50	50	20	50	50	300	
базовые	—	—	—	100	50	100	30	30	50	20	50	20	300	
Подвижные станции: (11)						(12) С излучением			(6) При мощности		(13) В полосе 156—174 Мгц	(13) Вне полосы 156—174 Мгц		
						(14) Класс A1	(15) других классов		≤5 вт (8)	>5 вт (8)				
судовые (16)	1000		—	300		300	50		100	50	20	50	300	
(17) спасательных средств	5000		—	300		200			100	50	20	50	300	
судовые аварийные	5000		—	—		—			100	50	—	—	300	
самолетные	500		—	100		100			100	50	50	50	300	
											(6) При мощности			
											≤5 вт (8)	>5 вт (8)		
(18) наземные	—		—	300		200			100	50	50	20	300	
				(6) При мощности									(3) В полосе	
				≤200 вт (8)	>200 вт (8)								470—2450 Мгц	2450—10 500 Мгц (7)
(19) Станции радиоопределения	100		—	100	50	—			200	200	50		500	3000
									(6) При мощности					
									≤50 вт (8)	>50 вт (8)				
(20) Радиовещательные станции	10 гц (21)		10 гц (21)	20		15			50	20	20		100	—
									(6) При мощности					
									≤100 вт (8)	>100 вт (8)	≤100 вт (8)	>100 вт (8)	≤100 вт (8)	>100 вт (8)
(22) Телевизионные станции (звук и изображение)	—		—	—		—			100	500 гц (21)	100	1000 гц (21)	100	1000 гц (21)

Key: (1). Frequency stability. (2). Category of radio stations. (3). in band ... kHz. (4). Fixed/recorded stations. (5). in band. (6). at power. (7). kHz. (8). W. (9). Ground stations. (10). coast. air services. base. (11). Movable stations. (12). With emission. (13). Outside to band ... MHz. (14). Class. (15). other classes. (16). shipboard. (17). rescue facilities; shipboard emergency; aircraft. (18). ground-based. (19). Stations of radio-determination. (20). Broadcasting service. (21). Hz. (22). Television stations (sound and image).

FOOTNOTE [1]. For the equipment RRL in the band 2450-10500 MHz the norm composes 50 millionths.

[2]. For emissions with necessary bandwidth, which exceeds 3 MHz, norm composes 300 millionths. ENDFOOTNOTE.

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This norm is raised to 60 dB for the transmitters with an average/mean power of more than 50 kW, moreover it is recommended so that the power of any spurious radiation would not exceed 50 mW, and it is reduced to 30 dB for the movable radio aids with a power of below 5 W; for the movable means the spurious radiations must not exceed 200 mW.

For newly constructed transmitters, which work in band of frequencies of 30-235 MHz, which have average/mean power more than 25 W, analogous norm is -60 dB, but not more than 1 mW. For the radio transmitters with an average/mean power of 25 W and less - 40 dB, but not more than 25 μW; for ChM of radio-telephone equipment of the marine movable service, which uses frequencies it is more than 30 MHz, are established/installed more harsh norms.

For transmitters, which use frequencies it is above 235 MHz, one should take measures for maximum decrease in level of spurious radiations.

Fig. 6.2 gives recommended MKKR (1966) norm to spurious radiations of radio transmitters $P_{\text{поб ср}}/P_{\text{осн ср}}$, which work in the range from 10 kHz to 960 MHz. For the radio transmitters, which work in the frequency band from 10 kHz to 30 MHz, the average/mean power of any spurious radiation, supplied to the feeder of antenna system, coincides with the given norms (curve A).

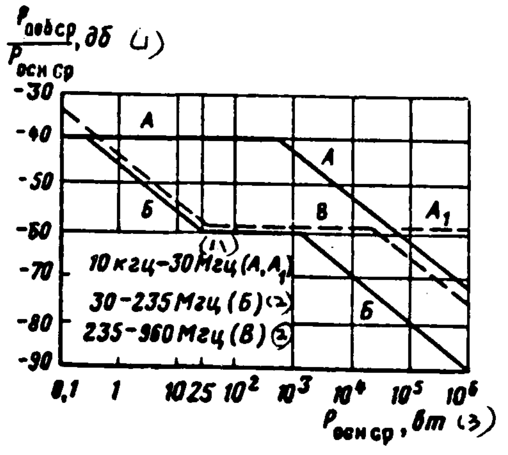

Fig. 6.2.

Key: (1). dB. (1a). 10 ... kHz ... MHz. (2). ... MHz. (3). ..., W.

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For the transmitters with a power output it is more than 50 kW, which can work on two either more frequencies, in the range of frequencies from the octave or it is above, it is not always expedient to suppress interference more than on 60 dB (curve A_1).

For radio transmitters, which work in band of frequencies of 30-235 MHz, norms also coincide with those given (curve B).

For radio transmitters with average/mean power at fundamental frequency it is more than 25 W, frequencies of 235-960 MHz working in band, average/mean power of any spurious radiation, which enters antenna, it must be not less than on 60 dB lower than radiated power at fundamental frequency, but is not above 20 mW, for transmitters by power it is less than 25 W in band of frequencies of 235-470 MHz - not above 25 μW (curve B).

6.4. Norms to some parameters EMS for the radio relay lines and the radio communication links, which use ISZ [ARTIFICIAL EARTH SATELLITE].

Let us examine question of normalization of parameters, which ensures electromagnetic compatibility of radio communication links, which use ISZ as repeater, with other radio-electronic means, which work in overall band of frequencies of 3-10 GHz, recommended for such radio communication links and which coincides in essence with frequency bands, utilized for radio relay lines of sight [8, 9].

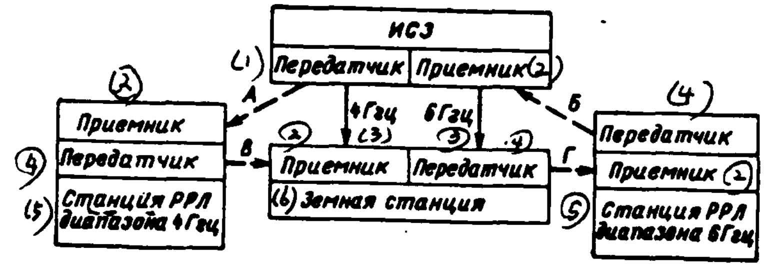

Fig. 6.3.

Key: (1). Transmitter. (2). Receiver. (3). GHz. (4). Transmitter. (5). Station RRL of range ... GHz. (6). Terrestrial station.

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Combined use of radio frequencies by radio communication links, which use ISZ, and by radio relay lines of sight (Fig. 6.3) can be provided, if following fundamental requirements are fulfilled:

A) signals, emitted with ISZ, must not create inadmissible interferences with receivers RRL stations;

B) signals, emitted by transmitters RRL, must not create inadmissible interferences with receivers ISZ;

C) signals, emitted by transmitters RRL, must not create inadmissible interferences with receivers of terrestrial stations of radio communication links, which use ISZ;

D) signals, emitted by terrestrial stations of radio communication links, which use ISZ, must not create inadmissible interferences with receivers RRL stations.

For fulfilling of these requirements is recommended following: the restricting of spectral density of power flux on surface of Earth, created caused by emissions of space station of communication satellite, so that it would not exceed $\left(-152+\frac{\theta}{15}\right)$ dB $\frac{W}{m^2}\frac{1}{4kHz}$, where θ - angle of arrival of wave to surface of Earth, measured in degrees, and to also restrict level of virtual rating, emitted by terrestrial station of service of communication satellites in any direction in horizontal plane so that it would not exceed 55 dBW in any band with width of 4 kHz [8, 9].

Let us note that exception/elimination is allowed/assumed in two cases: if distance from terrestrial station to boundary with adjacent country of more than 400 km, then norm 55 dBW can be increased on 2 dBW by every 100 km of distance, which exceeds 400 km; during agreement between interested countries is admissible weakening norm (not more than to 65 dBW in any band with width of 4 kHz).

Furthermore, it is recommended so that transmitting antenna terrestrial stations would work with angles of elevation, not less than 3° (angle of elevation it is measured between horizontal plane and central axis of major lobe/lug).

With fulfillment of these recommendations is provided normal operation of radio relay lines of sight, on which act emissions both of terrestrial and space stations of radiolink systems, which use ISZ.

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So that radio relay lines of sight would not interfere with communication systems, which use ISZ, is necessary fulfillment of following recommendations. Maximum power, effectively emitted antenna of the transmitter of radio relay line, must not exceed 55 dBW, and the power of transmitters, applied to the input of antenna, must not exceed 13 dBW. During the establishment of these norms they proceeded from the fact that the effective power of terrestrial stations comprises order 95 dBW. The first norm (55 dBW) provides protection of receivers ISZ from the short-term interferences, caused by the emission of the major antenna lobe of ground station RRL, the second (13 dBW) - from the prolonged interferences, created by the emissions of the minor lobes of the large number of antennas of radio-relay stations.

During layout of new routes of radio relay lines one should arrange/locate stations so that angle between direction of major antenna lobe and direction to steady-state orbit of communication satellite would be not less than 2°. If it is not possible to fulfill this recommendation, then the effective radiated power of radio-relay station in the direction to the steady-state orbit up to the value of 47 dBW must be limited. In this case the radiated power must not exceed 47 dBW in such a case, when antennas RRL are oriented into the part of the space, which is within the limits of less than 0.5° from the orbit of stationary satellites. If the orientation of antennas RRL varies within the limits of 0.5-1.5° from the direction in orbit of stationary satellites, then radiated power must linearly vary from 47 to 55 dBW respectively.

6.5. Norms of the permissible industrial radio interferences.

All-Union norms of permissible industrial radio interferences are introduced from 1 July, 1963, for that newly projected/designed, developed/processed and that produced by electro- and radio equipment of equipment, aggregates/units and mechanisms. Norms to the analogous devices/equipment, prepared until 1 July, 1963, were introduced from 1 January, 1967, [3]. In 1966 on the base of accumulated experience of the application of norms were developed and affirmed the supplements and changes to them [4].

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The main target of the norms - guarantee of more qualitative reception/procedure of television, radio broadcasting and work of other radio-electronic means accepted, which work in the band of frequencies of 0.15-400 MHz, in which are created the greatest industrial radio interferences, which last to 1 s (at the repetition frequency of more than 6 times 1 min for the devices/equipment of industrial designation/purpose, not connected to the networks/grids of apartment houses, and more than 1 time 5 min for other electrical equipment) and it is more than 1 s (independent of repetition frequency).

Introduction of norms forced ministries, departments, scientific research, design, design, construction, assembling, production and operating enterprises, and also individual owners of equipment, which can create radio interferences, conduct great work in order to accomplish established/installed requirements. Only the part of the equipment, intended for the underground objects, could work without the anti-interference devices/equipment. The installation of the latter was not required, if in the enterprises, in which was operated the equipment, which is the source of radio interferences, was provided the complex suppression of these interferences. Norms are not propagated also to the emissions, intended for the transmission of information, to the spurious radiations of radio transmitters, or to the pulse interferences, created by switches and knife switches.

Let us give norms to interferences from high-frequency installations, industrial, scientific and medical applications.

Harmful interferences with radio-electronic means must be absent with work of high-frequency installations of industrial designation/purpose at following frequencies: 18 kHz ±7.5%, 22 kHz ±7.5%, 44 kHz ±10%, 66 kHz $^{+12\%}_{-10\%}$.

Interferences from high-frequency industrial installations must not exceed values, indicated in p. 5 of Table 6.2, if they work at following frequencies: 440 kHz ±2.5%, 880 kHz ±1%, 1760 kHz ±2.5%, 5280 kHz ±2.5%, 13560 kHz ±1%, 27120 kHz ±1%, 4068 MHz ±1%, 81.36 MHz ±1%, 152,5 MHz±1%, ~~300.0~~ MHz ±1%, 2375.0 MHz ±2%, 22.125 GHz ±0.5%. In this case the frequency of 81.36 MHz in the zone of action of television channel

III it is permitted to utilize when field level of radio interferences from the high-frequency installations, which work at this frequency, at a distance of 50 m will not exceed 50 μV.

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Harmful interferences must be absent with work of high-frequency scientific and medical installations in bands of frequencies of 22 kHz ±7.5% and 66 kHz $^{+12\%}_{-10\%}$, and also in following frequency bands: 13560 kHz ±0.05%, 27120 kHz ±0.6%, 40.68 MHz ±2%, 1525 MHz ±1%, 460 MHz ±1%, 2375 MHz ±2%, 22.125 GHz ±0.5%.

Interferences from high-frequency scientific and medical installations must not exceed values, indicated in p. 5 of Table 6.2, if they work at following frequencies: 440 kHz ±2.5%, 880 kHz ±1%, 1760 kHz 2.5%, 5280 kHz ±2.5%.

Quantitative values of permissible levels of industrial radio interferences from other sources of interferences are given in Table 6.2.

State inspection of electrical communication of Ministry of Communications of USSR if necessary determines, to what point/item table 6.2 of norms should be related these or other devices/equipment - sources of interferences.

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6.5.1. Recommendations, directed toward the limitation of industrial radio interferences.

Let us examine recommendations, which facilitate noise suppression, created by high-frequency installations of industrial designation/purpose in the range of frequencies of 0.15-400 MHz [5, 6].

For effective anticountermeasure, caused by application of high-frequency electrothermics and appearing in this case strong electromagnetic fields, which interfere with reception of television, radio broadcast, etc., are developed recommendations. They are destined for the enterprises, which develop, design and operate the high-frequency installations of industrial designation/purpose.

Combating interferences of such type is conducted during interaction of state inspection of electrical communication and state sanitary inspection. The owners of high-frequency installations do not have a right to operate them without the recording in the local organs of the inspection of electrical communication.

Table 6.2.

(1) Источники радиопомех	(2) Допускаемый уровень поля радиопомех, мкв (4) В полосе частот (5) 0,15—0,5 Мгц	>0,5—2,5 Мгц	>2,5—20 Мгц	>20—100 Мгц	(6) При измерении на расстоянии	(3) Допускаемый уровень напряжения радиопомех, мкв В полосе частот (5) 0,15—0,5 Мгц	>0,5—2,5 Мгц	>2,5—20 Мгц	>20—100 Мгц	(7) При измерении
(8) Электроустройства, эксплуатируемые в жилых домах и подключаемые к их электрическим сетям 1	100	50	50	50	(9) 2 м от источника	200	100	100	200	(10) На зажимах
(11) Электротранспорт и связанные с ним устройства автоматизации, сигнализации и блокировки[1]: (12) Подвижной состав в установившихся режимах работы (на ровных участках контактной сети): (13) Городской и пригородный	50	20	10	20	(14) 10 м от оси пути	—	—	—	—	
(15) Магистральный и промышленный	100	50	20	50		—	—	—	—	
(16) Подвижной состав в переходных режимах и при прохождении устройств автоматизации, сигнализации и блокировки	250	100	50	100		—	—	—	—	
(17) Тяговые подстанции городского и железнодорожного транспорта	50	20	10	20	(18) 10 м от границы подстанции	—	—	—	—	
(19) Устройства с двигателями внутреннего сгорания с электрической системой зажигания (общего применения — автомобили, автобусы, мотоциклы, мопеды, силовые установки и др.)	—	—	—	20	(20) 10 м от источника	—	—	—	—	
(21) Радиовещательные и телевизионные приемники 2: (22) Гетеродины УКВ ЧМ блоков радиовещательных приемников	—	—	—	200	(23) 3 м от источника	—	—		—	—
(24) Гетеродины телевизионных приемников	—	—	—	30	(23) 30 м от источника	—	—	—	—	
(25) Генераторы развертки и другие устройства	50	20	10	—	(23) 2 м от источника	100	50	20	—	(26) На зажимах
(27) Высокочастотные установки различного применения: (28) Высокочастотные установки промышленного применения: (29) Установки, которые могут эксплуатироваться в жилых домах или подключаться к домовым электрическим сетям 3: (30) При выпуске	100	50	20	50	(31) 10 м от установки	250	100	50	—	(32) На электрощите, питающем установку, на расстоянии 10 м
(33) При эксплуатации										(34) На электрощите, питающем установку

Key: (1). Sources of radio interferences. (2). Permissible level of field of radio interferences, μV. (3). Permissible voltage level of radio interferences, μV. (4). In frequency band. (5). ... MHz. (6). In measurement at a distance. (7). In measurement. (8). Electrical equipment, operated in apartment houses and connected to their electrical networks [1]. (9). ... from source. (10). On terminals/grippers. (11). Electric transport and connected with it devices/equipment of automation, signaling and blocking. [1]. (12). Rolling stock in steady-load conditions (in even sections of overhead electric transport power line). (13). Urban and suburban. (14). 10 m of axis of path. (15). main-line and industrial. (16). Rolling stock and transient modes and with passage of devices/equipment of automation, signaling and blocking. (17). Traction substations of urban and rail transport. (18). 10 m of boundary of substation. (19). Devices/equipment with internal combustion engines with electrical ignition system (overall application - autos, buses, motorcycles, mopeds, power plants, etc.). (20). 10 m of source. (21). Broadcast and television receivers [2]. (22). Heterodynes of VHF FM units of broadcast receivers. (23). 30 m of source. (24). Heterodynes of television receivers. (25). Sweep oscillators and other devices/equipment. (26). on terminals/grippers. (27). High-frequency installations of different application. (28). High-frequency installations of industrial application. (29). Installations, which can be operated in apartment houses or be connected to house electrical networks [3]. (30). During issue. (31). 10 m of installation. (32). On electrical shield, which feeds installation, at a distance of 10 m. (34). On electrical shield feeding installation.

FOOTNOTE [1]. For the sources of short-term interferences is allowed/assumed the following excess of norms: for the electrical heating instruments with the temperature controls - 15 times; for the elevators - 15 times (measurements are conducted to 20 MHz); for the commercial automatic machines - 4 times (on the voltage/stress) and 8 times (on the field); for the everyday devices/equipment, not connected to electrical networks (for example, electric toys) - 3 times.

[2]. Norm 60 μV is allowed/assumed for receivers of XI and XII television channels 60 μV.

[3]. Under operating conditions excess of norm to 25% is allowed/assumed.

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Table 6.2. Continued.

(1) Высокочастотные установки различного применения	(2) Высокочастотные установки промышленного применения	(3) Установки, предназначенные для эксплуатации на промышленных и других предприятиях (вне жилых домов)	(4) При выпуске	(5) 1500—в полосах частот, выделенных настоящими „Нормами..."				(6) 30 м от установки	250	100	50	—	(7) На электрощите, питающем установку, на расстоянии 30 м
				(8) 50 — вне полос частот, выделенных настоящими „Нормами..."									
			(9) При эксплуатации	(10) 1500 — в полосах частот, выделенных настоящими „Нормами..."				(6) 30 м от установки	—	—	—	—	
				(8) 50 — вне полос частот, выделенных настоящими „Нормами..."				(11) За пределами предприятия в 10 м от границы территории	250	100	50	—	(12) В любой электросети с напряжением не выше 220 в, пересекающей границу предприятия и заходящей в жилые дома—на распределительных устройствах жилых домов
	(13) Высокочастотные установки медицинского и научного применения*	(14) Установки, эксплуатируемые в жилых домах или подключаемые к домовым электрическим сетям**		100	50	20	50	(15) 10 м от установки	—	—	—	—	(16) В любой электросети на расстоянии 10 м
		(17) Установки, эксплуатируемые на предприятиях, расположенных вне жилых домов и не связанные с электросетями жилых домов						10 м от границы предприятия					(18) На проводах воздушных сетей, пересекающих границу предприятия
(19) Линии электропередач (ЛЭП)***				100	50	20	10	(20) [illegible]0 м от ЛЭП	—	—	—	—	
(21) Объекты на выделенных территориях или в отдельных зданиях, не связанные с электрическими сетями жилых домов (промышленные, медицинские, энергетические и др., в т. ч. АТС не более 100 номеров, коммутаторы междугородных телефонных станций и др. предприятия связи)			(22) С воздушными сетями	100	50	20	50	(23) 10 м от границы объекта	250	100	50	—	(24) На проводах сетей, пересекающих границу предприятия
			(25) С кабелированными сетями						—	—	—	—	
(26) Электроустройства, эксплуатируемые вне жилых домов и не связанные с их электрическими сетями			(27) Передвижные	250	100	50	50	(28) 10 м от источника	1000	500	200	—	(29) На зажимах
			(30) Стационарные****	—	—	—	—						

Key: (1). High-frequency installations of different application. (2). High-frequency installations of industrial application. (3). Installations, intended for operation in industrial and other enterprises (out of apartment houses). (4). During issue. (5). 1500 - in bands of frequencies, isolated with present "Norms ...". (6). ... from installation. (7). On electrical shield, which feeds installation, at a distance of 30 m. (8). 50 - out of frequency bands, isolated with present "Norms...". (9). During operation. (10). 1500 - in bands of frequencies, isolated with present "Norms...". (11). Beyond limits of enterprise 10 m from boundary of territory. (12). In any electric system with voltage not higher than

220 V, that intersects boundary of enterprise and enveloping in apartment houses - on distributing devices/equipment of apartment houses. (13). High-frequency installations of medical and scientific application [1]. (14). Installations, operated in apartment houses or connected to house electrical networks [2]. (15). In any electric system at a distance of 10 m. (16). Installations, operated in enterprises of apartment houses arranged/located out of apartment houses and not connected with electric systems. (17). 10 m of boundary of enterprise. (18). On wires of aerial networks, which intersect boundary of enterprise. (19). Electric power lines (LEP) [3]. (20). 50 m of LEP. (21). Objects on isolated territories or in separate assignments, not connected with electrical networks of apartment houses (industrial, medical, energy, etc., including ATS of not more than 100 numbers, the commutators of toll offices, etc. of the enterprise of communication). (22). With overhead networks. (23). 10 m of boundary of object. (24). On wires of networks, which intersect boundary of enterprise. (25). Movable. (26). Electrical equipment, operated out of apartment houses and not connected with their electrical networks. (27). Movable. (28). 10 m of source. (29). On terminals/grippers. (30). Stationary [4].

FOOTNOTE [1]. Norms do not relate to the devices/equipment, which work at frequencies, isolated with present "Norms...".

[2]. In the range of VHF on harmonics, which do not fall into television channels, excess of norms 10 times is allowed/assumed.

[3]. For LEP with voltage more than 220 kV - at a distance of 100 m, if

LEP is not passed through populated areas and if LEP does not create radio interference.

*. Norms are fulfilled only on demand of client.

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Table 6.2. Continued.

(1) Аппаратура и оборудование проводной связи (кроме указанных в других пунктах таблицы)	(2) Станции местной телефонной связи	(3) Автоматические до 100 номеров	(4) Учрежденческие		250	100	50	200	(5) 2 м от источника	1000	500	200	1000	(6) На линейных и питающих проводах
			(7) Сельские						(8) 10 м от автозала					
		(9) Ручные	(10) Коммутаторы с количеством номеров	(11) До 100	100	50	30	50	(5) 2 м от источника	250	100	50	200	
				(12) Более 100	100	50	30	10	(13) 10 м от коммутаторного зала	250	100	50	100	
			(14) Звонки, индукторы, полюсопереключатели и др.		100	50	30	50	(5) 3 м от источника	1000	500	200	1000	(15) На зажимах
	(18) Станции дальней связи	(16) Телефонной			100	50	30	50	(17) 10 м от аппаратного зала	250	100	50	200	(6) На линейных и питающих проводах
		(19) Телеграфной и фототелеграфной, эксплуатируемые	(20) В нежилых зданиях при любом питании, кроме электрических сетей жилых домов		100	50	30	50	(5) 2 м от источника	250	100	50	—	(15) На зажимах
			(21) В жилых домах или при питании от их электрических сетей		50	30	10	50		100	50	30	200	
(22) Источники питания РЭС и средств связи (кроме самолетных)	(23) Генераторы, умформеры, инверторы и вибропреобразователи	(24) Приемных и переговорных устройств мощностью	(25) До 0,5 квт		2	2	2	2	(5) 1 м от источника	30	10	10	10	
			(26) Более 0,5 квт		30	10	10	10		250	100	50	50	
		(27) Передающих и других устройств в корпусах	(28) Неметаллических		—	—	—	—						
			(29) Металлических		—	—	—	—		1000	500	200	1000	(30) На зажимах и на корпусе
	(31) Динамические усилители, инверторы и умформеры передающих и специальных устройств со стороны		(32) Переменного тока и высокого напряжения постоянного тока		—	—	—	—		1000	500	200	200	
			(33) Низкого напряжения постоянного тока		—	—	—	—		100	50	30	30	
	(34) Передвижные электростанции, агрегаты и другие источники питания разного напряжения в двух вариантах		(35) Первый		2	2	2	2	(5) 1 м от источника	30	10	10	10	
			(36) Второй		30	10	10	50	(5) 10 м от источника	250	100	50	200	

Key: (1). Equipment and the devices of wire communication (besides those indicated in other points/items of table). (2). Stations of local telephone communication. (3). Automatic to 100 numbers. (4). Institutional. (5). ... from source. (6). On linear and power leads. (7). Rural. (8). 10 m from auto hall. (9). Manual. (10). Commutators with quantity of numbers. (11). To. (12). It is more. (13). 10 m from switchboard hall. (14). Bells, inductors, pole changers, etc. (15). On terminals/grippers. (16). Telephone. (17). 10 m from equipment room. (18). Telecommunication stations. (19). Telegraph and phototelegraphic, operated. (20). In uninhabited buildings with any feed, except electrical networks of apartment houses. (21). In apartment houses or with feed from their electrical networks. (22). Supplies of power RES and means of communication (besides aircraft). (23). Generators, dynamotors, inverters and vibrapacks. (24). Receiving and intercoms by power. (25). To 0.5 kW. (26). More than 0.5 kW. (27). Transmitting and other devices in housings. (28). Nonmetallic. (29). Metallic. (30). On terminals/grippers and on housing. (31). Dynamic amplifiers, inverters and dynamotors of transmitting and special devices from side. (32). Alternating current and high DC voltage. (33). Low DC voltage. (34). Movable power plants, aggregates/units and other supplies of power of different voltage in two versions. (35). First. (36). Second.

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(1) Устройства, эксплуатируемые вблизи служебных радиоприемных установок; (2) Электрические машины и оборудование (в том числе радиотехнические средства судов); (3) Для объектов в корпусах; (4) Неметаллические	–	–	–	–		250	100	50	50	(6) На зажимах и на корпусах
(5) Металлические	–	–	–	–	–	1000	500	200	1000	
(7) Механизмы управления, вращения и коммутации антенн	2	2	2	2	(8) 1 м от источника	20	10	10	10	
(10) Аппаратура проводной связи (телефонная, телеграфная и фототелеграфная), уплотнения, радиостанций, радиотелеграфное оборудование и др.	2	2	2	2	(8) 1 м от источника	20	10	10	10	(9) На зажимах
(11) Судовая навигационная аппаратура	–	–	–	–		250	100	50	50	
(12) Автомототранспорт специального назначения					(8) 1 м от источника	20	10	10	10	(13) На зажимах аккумулятора
(14) Двигатели внутреннего сгорания; (15) Авиационные, судовые и др. транспортные средства	2	2	2	2	(8) 3 м от источника	–	–	–	–	
(16) Малолитражные мощностью до 12 л. с.										
(22) Оборудование самолетов; (17) Генераторы постоянного тока мощностью; (18) До 3 квт	–	–	–	–		100	50	20	20	
(19) 3 квт и более; (20) В цепи возбуждения	–	–	–	–						
(21) На главных шинах	–	–	–	–		500	100	50	50	
(23) Электродвигатели постоянного тока длительного действия	–	–	–	–		100	50	20	20	(9) На зажимах
(24) Электродвигатели и механизмы специального назначения кратковременного действия (не более 1 мин), включаемые за время полета не более 2 раз	–	–	–	–		1000	500	200	200	
(25) Инверторы переменного тока для питания бортовой сети со стороны; (26) Постоянного тока	–	–	–	–		100	50	20	20	
(27) Переменного тока	–	–	–	–		250	100	50	50	
(28) Навигационные приборы и другое специальное оборудование, питаемое от бортовой сети; (29) Постоянного тока	–	–	–	–		100	50	20	20	
(30) Переменного тока	–	–	–	–		250	100	50	50	

Key: (1). Devices/equipment operated near the official radio-receiving installations. (2). Electrical machines and equipment (including radio equipment of vessels. (3). For objects in housings. (4). Nonmetallic. (5). Metallic. (6). On terminals/grippers and on housings. (7). Mechanisms of control, rotation and commutation of antennas. (8). ... from source. (9). On terminals/grippers. (10). Equipment of wire communication (telephone, telegraph and phototelegraphic), multiplexing, radio stations, radiotelegraph equipment, etc. (11). Shipboard navigation aid. (12). Special-purpose motor vehicle transportation. (13). On terminals/grippers and on housings. (14). Internal combustion engines. (15). Aviation, shipboard, etc. transportation means. (16). Small-capacity with power to 12 l. s. (17). Direct-current generators by power. (18). To 3 kW. (19). 3 kW and more. (20). In energizing circuit. (21). On main busbars. (22). Equipment of aircraft. (23). Electric motors of direct current of prolonged action. (24). Electric motors and special-purpose mechanisms of short-term action (not more than 1 min), switched on for flight time not more than 2 times. (25). Inverters of alternating current for feed of aircraft electrical wiring system from side. (26). Direct current. (27). Alternating current. (28). navigational instruments and other special equipment, supplied from aircraft electrical wiring system.

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The latter do not record high-frequency installations in the presence of the interferences, which exceed the tolerance level. For reduction in the interferences the common shadowing of installations, which is permitted by inspection only with the preliminary written agreement of the organs/controls of sanitary inspection, is required. Thus both inspections have the capability to fight with the radio interferences, which interfere with radio-electronic means or which create the inadmissible working conditions for the service personnel (from the point of view of the biological effect of interferences to the man).

According to sanitary regulations maximum permissible levels of electric intensity from industrial high-frequency installations are 20

V/m in frequency band from 100 kHz, to 30 MHz, 5 V/m - from 30 to 300 MHz; intensity/strength of magnetic field in band of frequencies of 100 kHz - 3 MHz must not be more than 5 A/m.

As far as level of permissible industrial radio interferences is concerned, n it is regulated by all-Union norms and to supplements to them, examined earlier. It should be noted that from 1 January 1970. the operation of the high-frequency installations, working out of the limits of the chosen frequency bands and released to making of a decision about these frequency bands, is forbidden.

However, on what it is necessary to focus attention during development of high-frequency installations of industrial designation/purpose? Besides the solution of the questions, connected with the straight/direct designation/purpose of installations, it is necessary to remove background radiation from the separate elements of installation. For this it is necessary to reveal the elements, which create interferences, to establish/install requirements for the effectiveness of noise suppression and economic aspects of fulfilling these requirements. During the design of installations should be solved the problems of shadowing, filtration and decoupling. The system of interference suppression must satisfy simultaneously the requirements of the norms of the permissible industrial radio interferences and sanitary regulations. Reduced the level of radio interferences should be in essence due to the correct selection of diagram, constructing/designing of the nodes and the materials used.

During development of diagram it is necessary to select anodic dissent and oscillator circuit so that maximum filtration of harmonics would be achieved.

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Most advisable method of noise suppression is unit-by-unit shadowing of high-frequency elements: generator, anodic transformer, rectifier and working element. If all these elements are mounted in one cabinet, then it must possess the necessary shadowing. Cabinet must be prepared from sheet steel with the welded joint between the separate sheets and to be electrically airtight. Vent openings and filtering element are projected/designed from the same considerations, which were given in S5.3 about the shielding locations.

It is recommended so that the general/common effectiveness of the shadowing of cabinet would be 60-70 dB. This recommendation can be carried out, if is provided a sufficient electrical contact on the perimeter of all metallic parts of the section, in which the generator is placed, if are removed the background radiation, passing through different openings/apertures in the screen/shield (among other things through the ventilation system), and also their propagation along the electrical wires and the high-frequency cables.

Concrete/specific recommendations regarding noise suppression from high-frequency installations of different industrial designation/purpose (hardening/quenching, smelting of metal, drying of wood, cementing of wood panels, boiling of optical glass, etc.), and also from other sources of industrial radio interferences (electrical machines, electrical equipment of autos of general purpose with gasoline engines, railroad electric transport, electric welding equipment, electrical equipment of elevators, etc.) are given in documents of state inspection of electrical communication and individual departments, published from 1952 through 1968.

There is also series/row of Departmental technical specifications, recommendations, etc. according to the design of the installations of radio communication and radio broadcasting, transmitting and receiving radio centers, television stations, relay television stations and radio-houses, etc. In them industrial radio interferences are regulated, recommendations regarding the design, the production and testing of chokes/throttles for the suppression of these radio interferences, etc are given.

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It should be pointed out that for mutual connecting/fitting and eliminating multiplicity of standard reports/events about protection of radio reception from man-made interferences Council of Ministers of USSR in 1967 adopted resolution, according to which all norms were united, and previously resolutions of government of USSR for this question accepted lost force.

Council of Ministers of USSR established that working, and also newly made electrical equipment and transportation means, which are sources of industrial radio interferences, must be equipped compulsorily with protective devices, which ensure suppression of created by them interferences in accordance with existing all-Union norms, and that ministries, departments, enterprises and organizations do not have right to accept from suppliers production, if it does not satisfy the requirements of these norms, and also during design and construction of industrial enterprises they must provide for equipment by their systems of complex interference suppression in accordance with norms. The state committee of standards, with the Council of Ministers of the USSR is obligated to include in the newly developed/processed and reexamined state standards of requirement on elimination and suppression of industrial radio interferences. The ministries of Trade in the USSR and Union republics must permit the production of the consumer goods, which are the sources of man-made interferences, only in the case of the conformity of goods to norms to these of interferences.

Presence of devices, which ensure suppression of man-made interferences in motor vehicle transportation, trackless trolley buses and trolleys, must be monitored by state automobile inspection of ministry of internal affairs of USSR, and from remaining electrical equipment and transportation means - State inspection of electrical communication of Ministry of Communications of USSR.

For case, when man-made interferences interfere with radio reception, by Ministry of Communications of USSR and committee on radio broadcasting and television with Council of Ministers of USSR in 1967 affirmed instruction about order of reception and examination of corresponding statements. Instruction determines operational procedure, which reveal the sources of interferences, and measure for their elimination by the services of control/checking of the suppression of the industrial radio interferences of state inspection of the electrical communication of region (edge, republic). Measures for antijamming with the reception of radio broadcasting on the kilometer, hectometer and decametric waves are taken only in the case of the unsatisfactory reception of the radio stations, which ensure with broadcasting the zone, into which enters this region (edge, republic). Measures for antijamming with the reception of television and VHF FM broadcasting take only if these interferences are perceived in zone of the confident reception of television and VHF FM broadcasting. The territory, within limits of which the strength of the field of received signal comprises not less than 320 μV/m for television channels I and II, is considered the zone of confident reception, not less than 500 μV/m for television channels III-V, not less than 700 μV/m - for the remaining television channels (VI-XII) and not less than 200 μV/m - for VHF FM broadcasting. If interferences act on the receiving devices of television repeaters, then the search for interferences is conducted in all cases, except those, with which the strength of the field of useful signal is less than 50 μV/km at the height of 8-10 m above the Earth.

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7. QUESTIONS OF THE CALCULATION OF THE LEVELS OF RADIO INTERFERENCES AND SIMULATION IN THE REGION OF COMPUTER(S) RES.

7.1. Determination of three-dimensional/space and frequency separations between RES, WHICH CREATE INTERFERENCES.

Let us show how to define necessary three- dimensional/space separation, with which interference virtually does not affect passage of useful signal in receiving circuit, in the case of coinciding carrier frequencies of interacting equipment at any angle of incidence of radiation patterns of their antennas, and then - as to solve the same problem with noncoincidence of carrier frequencies and as to determine frequency separation between interacting equipment with assigned three-dimensional/space separation [1, 2].

Fig. 7.1 shows arrangement of interacting radio stations. At point A the receiver of working station is arranged/located, at point B - transmitter of jamming station, at point C - transmitter of the working station (for some types of radio equipment, for example for radars both the transmitter of working station and its receiver, they are located at one point, for example at point A). In fig. 7.1 α_1 - angle between the straight/direct AB, connecting point of the arrangement/position of the interacting stations, and the direction of the axis of the antenna of the receiver of working station; α_2 - angle between the same straight line AB and direction of the axis of the antenna of the transmitter of that mixing station; $\alpha_{гл\,раб}$ — angle, which characterizes the width of the main lobe of radiation of the receiving antenna of working station; $\alpha_{гл\,пом}$ — angle, which characterizes the width of the main lobe of radiation of the transmitting antennas jamming station.

To input of receiver of working station besides power of useful signal $P_{пр\,раб}$ enters interference with power $P_{пр\,пом}$, taken by antenna, that has in direction AB amplification $G_{пр\,раб}$.

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The transmitter of jamming station is characterized by power $P_{пер\,пом}$ and antenna gain $G_{пер\,пом}$ in direction BA.

From the figure one can see that if $\frac{\alpha_{гл\,раб}}{2} \geqslant \alpha_1$ and $\frac{\alpha_{гл\,пом}}{2} \geqslant \alpha_2$, that interference is emitted by major lobe of the radiation pattern of jamming station transmitting antennas, and is received as main lobe of radiation of receiving antenna of working station. If $180-\frac{\alpha_{з\,пом}}{2} < \alpha_2 < 180+\frac{\alpha_{з\,пом}}{2}$ and $180-\frac{\alpha_{з\,раб}}{2} < \alpha_1 < 180+\frac{\alpha_{з\,раб}}{2}$, then interference is emitted and is received by the rear lobes of the radiation patterns of the same antennas. Here $\alpha_{з\,раб}$ — angle, equal to the width of the rear lobe/lug of the radiation pattern of the receiving antenna of working station; $\alpha_{з\,пом}$ — angle, equal to the width of the rear lobe of the radiation pattern of the transmitting antenna of jamming station.

If $\alpha_2 > \frac{\alpha_{гл\,пом}}{2}$, and $\frac{\alpha_{гл\,раб}}{2} \geqslant \alpha_1$, then interference is emitted by lateral lobe, and is received by the main one. If $\frac{\alpha_{\text{тх пом}}}{2} \geqslant \alpha_2$, and $\alpha_1 > \frac{\alpha_{\text{тхрад}}}{2}$, then the interference is emitted by the major lobe, and is received as the main.

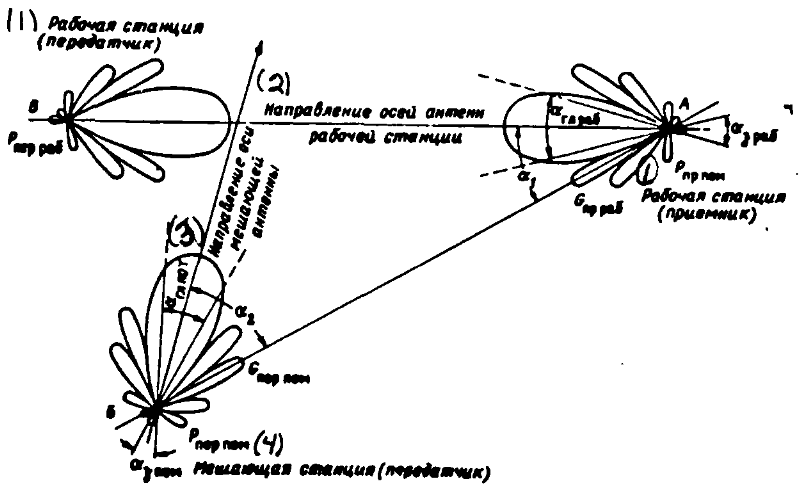

Fig. 7.1.

Key: (1). Working station (transmitter). (2). Direction of axes of antenna of working station. (3). Direction of axis of interfering antenna. (4). Jamming station (transmitter).

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The remaining relationships/ratios of angles $\alpha_{тл} > \frac{\alpha_{тл\ пом}}{2}$ and $\alpha_1 > \frac{\alpha_{тл\ раб}}{2}$ correspond to emission and reception/procedure of interference by the minor lobes of the radiation patterns of the jamming station transmitting antennas and the receiving antenna of working station.

To initial data for calculating interferences relate: bandwidth, which occupies useful emission; power of transmitters and their carrier frequencies; angles α_1 and α_2; antenna gain, their radiation pattern and height/altitude of suspension; weakening of interference due to noncoincidence of antenna polarization; loss in high-frequency transmitting and receiving circuits of interacting stations; required ratio of signal to interference at input of receiver of working station, necessary for work of radio equipment with assigned degree of quality; range of working station or length of line of communications; coefficient, which considers weakening interference of interference due to noncoincidence of carrier frequencies of interacting stations, and also due to difference between bandwidth, occupied by emission of jamming station, and passband of receiver of working station; the coefficients, which consider the change in the value of interfering action of interference, caused by nonuniform spectral distribution of the power of signal and interference, and weakening the interference of interference due to a change in the antenna gains of that interfering and the worker of stations during their rotation; the attenuation factor of field of the V due to the effect relief of the Earth during the emission of the signal and interference, tropospheric scattering, etc.

In certain cases can be required series/row of other parameters, such, for example, as antenna scan rate, operating area of receiving antenna, wave impedance of feeder, effective scattering cross section of target, etc.

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Power of interference, converted to input of receiver of working station (at point A in Fig. 7.1), is calculated with the aid of following relationship/ratio (all values - in decibels):

$$P_{\text{пр пом}} = P_{\text{пер пом}} + G_{\text{пер пом}} + G_{\text{пр раб}} - K_{\text{вч пом}} - K_{\text{распр}} - K_{\text{вч раб}} - K_{\text{поляр}} - K_{\text{спектр}} - K_{\text{к у}} - K_{\text{неравн}}, \quad (7.1)$$

where $P_{\text{пер пом}}$ — power of jamming transmitter of station, which is located at point B; $G_{\text{пер пом}}$ — factor of amplification of transmitting antenna of jamming station in direction BA; $G_{\text{пр раб}}$ — factor of amplification of receiving antenna of working station in direction AB; $K_{\text{вч пом}}$ — loss in high-frequency transmitting circuit of jamming station; $K_{\text{распр}}$ — fundamental losses of propagation on line of communications "jamming transmitter - working receiver"; $K_{\text{вч раб}}$ — loss in high-frequency receiving circuit of working station; $K_{\text{поляр}}$ — coefficient, which considers weakening interference due to noncoincidence of antenna polarization of worker and jamming station;

$K_{\text{спектр}}$ —coefficient, which considers weakening the interference of interference due to the noncoincidence of the carrier frequencies of the interacting stations, and also due to the difference between the bandwidth, occupied by the emission of jamming station, and the passband of receiver of working station; $K_{\text{к у}}$ — coefficient, that considers a change in the interference of interference due to a change in the antenna gains of that interfering and the worker of the stations of stations during the rotation of these antennas; $K_{\text{неравн}}$ — coefficient, which considers a change in the value of the interference of interference due to the nonuniformity of spectral distribution of the power of signal and interference.

It should be noted that determination of series/row of enumerated coefficients is complex problem, whose solution will require performing considerable theoretical and experimental work.

7.1.1. Determination of the space separation with the coincidence of the carrier frequencies of the interacting stations.

So that interacting stations, which work at one and the same carrier frequencies, would not prevent each other, it is necessary to determine the magnitude of required three-dimensional/space separation, i.e., minimum distance between source of interferences and working station, with which is provided assigned by initial data ratio of power of useful signal to power of interfering signal at input of receiver of working station $K_{\text{тр}}$.

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During the determination of three-dimensional/space separation first one type of equipment is accepted for the working station, another - for that interfering.

For determining value of three-dimensional/space separation it is necessary that inequality

$$K_{\text{тр}} \leqslant K_{\text{расч}}, \qquad (7.2)$$

where $K_{\text{расч}} = P_{\text{пр раб}}/P_{\text{пр пом}}$ — ratio of power of useful signal to power of interfering signal for input of receiver of working station, which corresponds to designed three-dimensional/space separation between interacting stations, would be fulfilled.

After expressing latter/last equation in decibels, we will obtain

$$P_{\text{расч}} = P_{\text{пр раб}} - P_{\text{пр пом}}. \qquad (7.3)$$

From equation (7.1) it is possible to determine minimally necessary fundamental losses of propagation on line of communications BA:

$$K_{\text{распр}} = P_{\text{пер пом}} - P_{\text{пр пом}} + G_{\text{пер пом}} + G_{\text{пр раб}} - K_{\text{вч пом}} - K_{\text{вч раб}} - K_{\text{поляр}} - K_{\text{спектр}} - K_{\text{ку}} - K_{\text{неравн}}.$$

Taking into account equations (7.2) and (7.3), we obtain:

$$K_{\text{распр}} \geqslant P_{\text{пер пом}} - P_{\text{пр раб}} + K_{\text{тр}} + G_{\text{пер пом}} + G_{\text{пр раб}} - K_{\text{вч пом}} - K_{\text{вч раб}} - K_{\text{поляр}} - K_{\text{спектр}} - K_{\text{ку}} - K_{\text{неравн}}. \qquad (7.4)$$

On the other hand, fundamental propagation loss of radio waves by length λ in free space to distance of R are equal to

$$K_{\text{распр}} = \left(\frac{4\pi R}{\lambda}\right)^2,$$

or

$$K_{\text{распр}}, \text{дБ} = 20 \lg \left(\frac{4\pi R}{\lambda}\right). \qquad (7.5)$$

Solving equations (7.4) and (7.5), it is possible to determine necessary three-dimensional/space separation between source of interferences and working station. This separation can be found also from the nomogram of fundamental propagation loss of radio waves in the free space, represented in Fig. 7.2 [1].

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Given reasonings are valid, if radio waves are propagated in free space. If this condition is not satisfied, should be considered the effect of the Earth: into formula (7.5) it is necessary to introduce attenuation factor V (during its determination stop we will not be).

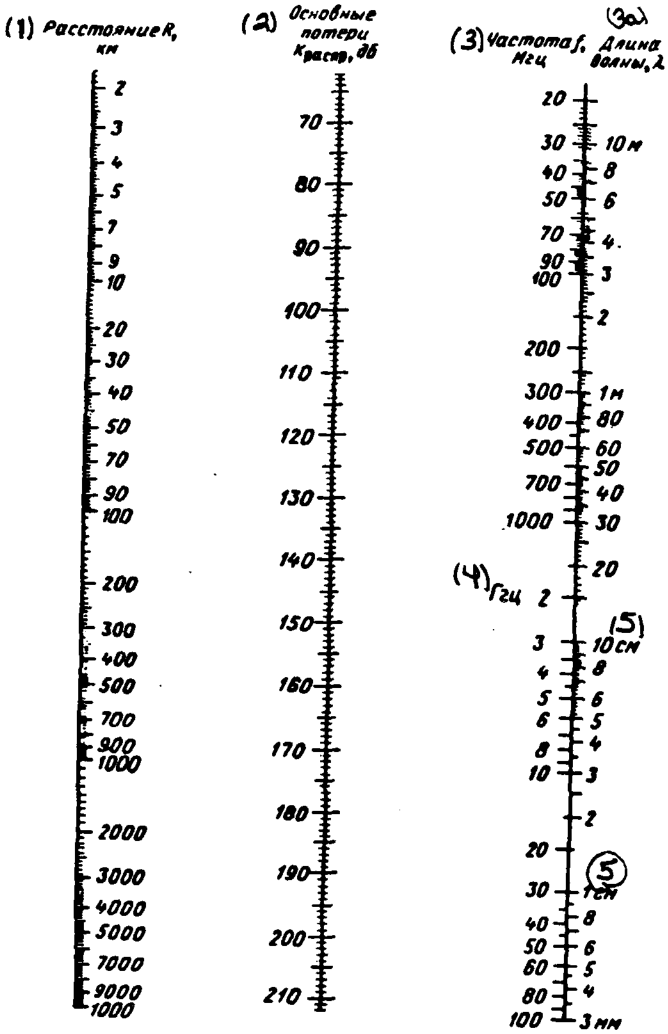

Fig. 7.2.

Key: (1). Distance R, km. (2). Fundamental losses ... by dB. (3). Frequency, MHz. (3a). Wavelength, λ. (4). GHz. (5). cm.

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The value of the minimally necessary attenuation on the route "jamming transmitter - working receiver" taking into account the effect of the Earth is equal to

$$K_{\bullet} = \left(\frac{4\pi R}{\lambda}\right)^2 \frac{1}{V},$$

or

$$K_{\bullet},\ d\mathit{B} = 20\lg\left(\frac{4\pi R}{\lambda}\right) - V,\ d\mathit{B} = K_{\text{расп}},\ d\mathit{B} - V,\ d\mathit{B}. \quad (7.6)$$

Solving equations (7.4) and (7.6), we obtain new value of attenuation on route K_0 and through it find minimally necessary distance of R between source of interferences and working station, ensuring required excess of signal above interference.

Then analogous calculation must be conducted for case, when station, initially accepted as worker, is considered interfering, and they accept as worker station, which was being considered interfering. As a result are obtained one additional value of the minimally necessary distance between the source of interference and the working station, ensuring required excess of the signal above the interference. Of two values, obtained as a result of the carried out calculations, for the value of the minimally necessary three-dimensional/space separation is accepted greatest.

If obtained result exceeds distance of straight/direct visibility $R_{\text{пр}}$, km, between source of interferences and working station, computed according to known formula

$$R_{\text{пр}},\ км = 4{,}12(\sqrt{h_{a1}} + \sqrt{h_{a2}}),$$

where h_{a1} — height of antenna of source of interferences, m; h_{a2} — height of antenna of working station, m, then interfering effect of source of interferences virtually is absent already beyond line-of-sight ranges. And, therefore, the interacting equipment in question can be placed out of the line-of-sight ranges. In this case, if the obtained value of the minimally necessary three-dimensional/space separation exceeds 100 km, should be determined the possibility of interfering effect of both the stations due to the tropospheric scattering of radio waves in question.

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7.1.2. Determination of the interfering effect of the interacting means as a result of the tropospheric scattering.

For determining possibility of mixing effects source of interferences, which enter input of receiver of working station as a result of tropospheric scattering, into formula (7.6) should be substituted the value of attenuation factor, conditioned by this scattering. As a result taking into account this factor will be required another value of the minimally necessary attenuation on the route "jamming transmitter - working receiver". In terms of this value is determined the minimally necessary three-dimensional/space separation between the working receiver and the jamming transmitter.

Let us pause in greater detail at determination of attenuation factor during tropospheric scattering.

Fig. 7.3 gives graph/curve of median value of attenuation factor F, exceeded during 50% of time, for frequencies from 100 to 4000 MHz and distances from 100 to 700 km, which considers tropospheric scattering. For determining field weakening, exceeded during another percent of time, it is necessary to amend, which consider slow and rapid fadings. The plotted function of distribution, which are subordinated to lognormal law, with the copper-feudatory fadings for the radio links of different length is shown in Fig. 7.4.

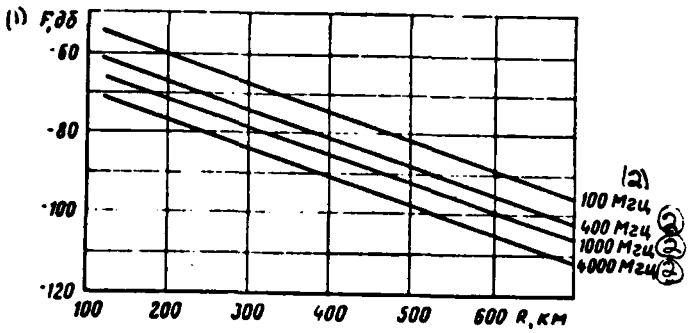

Fig. 7.3.

Key: (1). dB. (2). MHz.

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On the soy-beans of abscissas is deposited/postponed p - probability of the excess of the assigned signal level in %, while along the axis of ordinates - allowance P, dB with respect to the median value.

Plotted function of distribution, which obeys the law of Rayleigh, for rapid fadings is shown in Fig. 7.5 (curve n=1). Along the axis of abscissas is plotted p - probability of the excess of the assigned signal level in %, while along the axis of ordinates - allowance S, dB with respect to the median value. The allowances, obtained from Fig. 7.4 and 7.5, must be added to the value of the median value of the attenuation factor, found with the aid of the graph/curve Fig. 7.3.

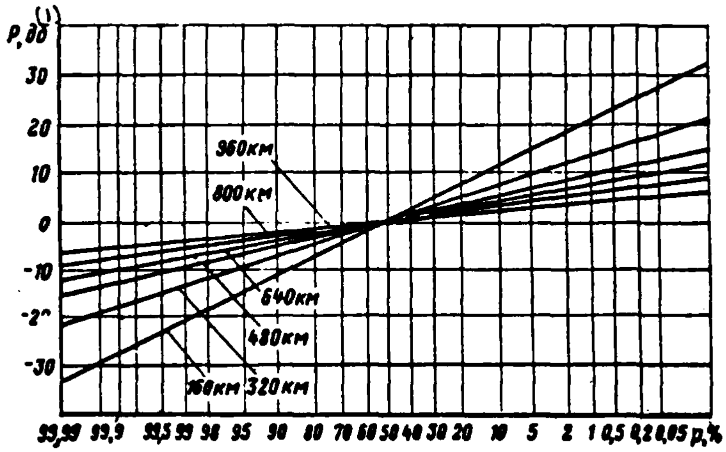

Fig. 7.4.

Key: (1). dB.

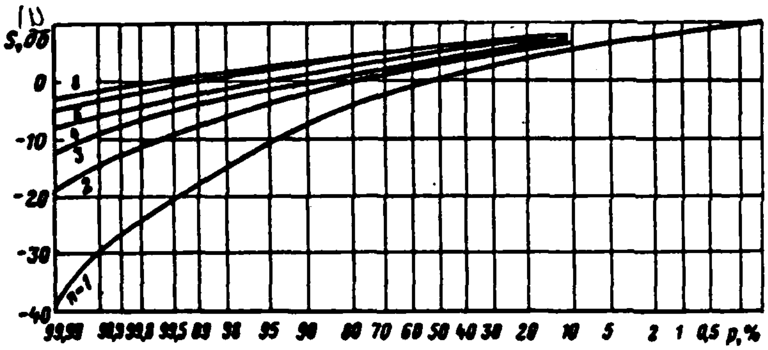

Fig. 7.5.

Key: (1). dB.

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The obtained sum will be equal to the attenuation factor of field V, exceeded during the assigned percentage of time.

However, in the case of applying three-dimensional/space and frequency selectivities, which are means of dealing with rapid fadings, is taken another correction, which corresponds to number of simultaneous separations used. In this case it is considered that the effect of frequency separation is equivalent to the effect of three-dimensional/space separation. Therefore, for example, the curve n=6 in Fig. 7.5 can correspond to the case, when reception/procedure is realized by the simultaneously four spaced in the space antennas at two different operating frequencies or by three spaced antennas at three different frequencies, etc.

Thus, taking into account new value of the multiplier of weakening from formula (7.6) it is possible to find new in value according to formula (7.6) it is possible to find new value of minimally necessary fundamental propagation loss K_0.

From obtained result it is necessary to deduct correction, which corresponds to losses of antenna gain. This correction can be determined with the aid of the curves of Fig. 7.6, according to which the losses of amplification grow/rise with an increase in the antenna gain, beginning from the factor of amplification G, approximately equal to 23 dB.

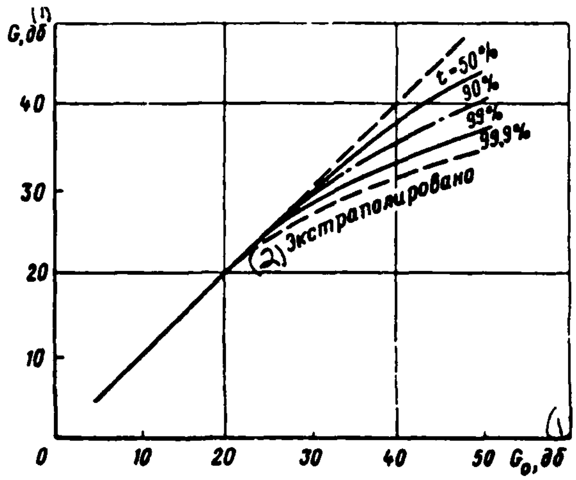

Fig. 7.6.

Key: (1). dB.

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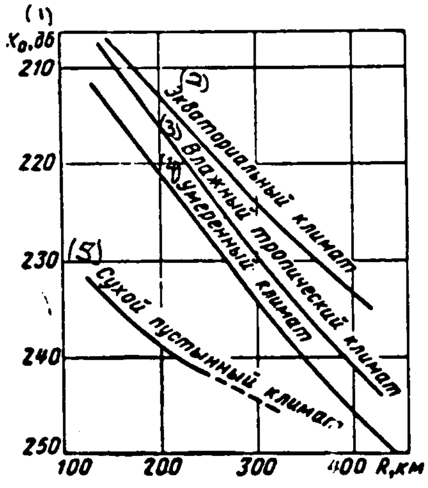
Allowance is determined by subtraction from the value of the antenna gain G_0 of the value of the realizable antenna gain G, which corresponds to the selected percentage of time T, during which this amplification is realized. Thus, for instance, correction for the antenna with the amplification 40 dB for 99% of time, during which this amplification is realized, is 40-33=7 dB.

Knowing value of minimally necessary weakening on route, according to graphs/curves of field weakening during tropospheric propagation, given in Fig. 7.7-7.9, it is possible to determine minimally necessary distance between source of interferences and working station. In this case weakening K_0, indicated in Fig. 7.7, is not exceeded during 99% of time and corresponds to the frequency of 1000 MHz. If field weakening at the point of reception/procedure is assigned with other percentage of time, then from the obtained according to formula (7.6) result should be deducted the time correction ΔK_{BP}, determined from the curve, depicted in Fig. 7.8. With 99% of correction time is equal to zero. But if frequency differs from 1000 MHz, then to the obtained according to formula (7.6) value of weakening, reduced by the value of temporary/time correction, it is necessary to add frequency correction ΔK_f, which should be determined on the curve, given in Fig. 7.9.



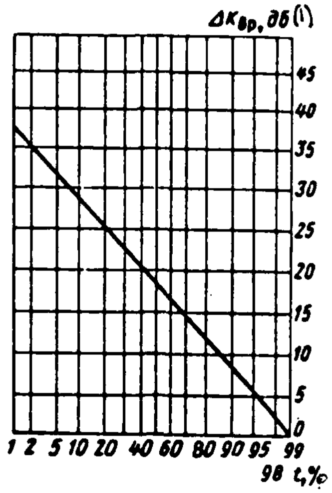


Fig. 7.7. Fig. 7.8.

Fig. 7.7. Key: (1). dB. (2). Equatorial climate. (3). Humid tropical climate. (4). Moderate climate. (5). dry desert climate.

Fig. 7.8. Key: (1). dB.

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Final result - the distance between the source of interferences and the working station - is located with the aid of the graphs/curves Fig. 7.7.

Analogous calculation is performed for case, when station, initially accepted as worker, is considered interfering, and they accept as worker station, which was being initially considered interfering.

For value of minimally necessary three-dimensional/space separation is accepted greatest of two values, obtained as a result carried out by this calculation procedure.

Value of necessary fundamental losses can prove to be by such that unknown distance, determined according to graphs/curves, will be less than 100 km. This means that the mixing effects source of interferences due to the tropospheric scattering it will not be, and jamming transmitter can be located in any place of the direction in question, which is located beyond the line-of-sight ranges.

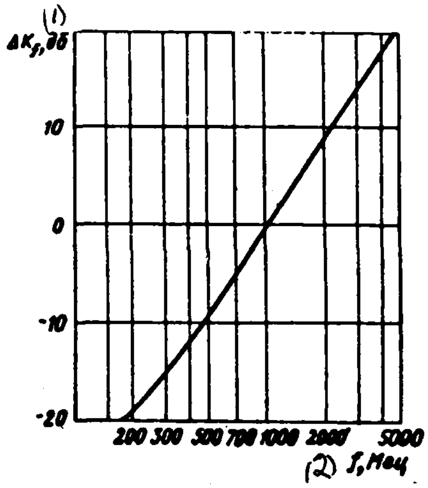

Fig. 7.9.

Key: (1). dB. (2). MHz.

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7.1.3. Calculation of three-dimensional/space separation with the noncoincidence of the carrier frequencies.

If carrier frequencies of interacting stations do not coincide, it is necessary to consider weakening interference of interference in high-frequency circuit and in receiving device of working station, caused by noncoincidence of frequencies of worker and jamming station. For this it is necessary to know $P_{пр\,пом.}$ that determined from formula (7.1), and the coefficients of weakening the interfering signal in high-frequency circuit $K_{вч}$ and in receiving device $K_{пр}$ of the working station, caused by the noncoincidence of the frequencies of the worker and jamming station.

In the considered case value of noise signal, converted to input of receiver of working station, is equal to

$$P_{\text{пр пом несовп}} = P_{\text{пр пом}} - K_{\text{вч}} - K_{\text{пр}},$$

or by analogy with formula (7.1):

$$\begin{aligned} P_{\text{пр пом несовп}} = {} & P_{\text{пер пом}} + G_{\text{пер пом}} + G_{\text{пр раб}} - K_{\text{вч пом}} - \\ & - K_{\text{распр}} - K_{\text{вч раб}} - K_{\text{поляр}} - K_{\text{разнес}} - K_{\text{спектр}} - \\ & - K_{\text{ку}} - K_{\text{неравн}} - K_{\text{вч}} - K_{\text{пр}}. \end{aligned} \tag{7.7}$$

So that interacting stations would not interfere with each other, is necessary the fulfilling of inequality (7.2). In this case, when

$$K_{\text{расч}} = P_{\text{пр раб}},\ dB - P_{\text{пр пом несовп}},\ dB,$$

inequality (7.2) takes the following form:

$$K_{\text{тр}} < P_{\text{пр раб}} - P_{\text{пр пом несовп}},$$

or

$$P_{\text{пр пом несовп}} < P_{\text{пр раб}} - K_{\text{тр}}. \tag{7.8}$$

Solving equations (7.7) and (7.8) relatively $K_{\text{распр}}$, we obtain

$$\begin{aligned} K_{\text{распр}} \geqslant {} & P_{\text{пер пом}} - P_{\text{пр раб}} + K_{\text{тр}} + G_{\text{пер пом}} + G_{\text{пр раб}} - \\ & - K_{\text{вч пом}} - K_{\text{вч раб}} - K_{\text{поляр}} - K_{\text{разнес}} - K_{\text{спектр}} - \\ & - K_{\text{ку}} - K_{\text{нерavn}} - K_{\text{вч}} - K_{\text{пр}}. \end{aligned} \tag{7.9}$$

Obtained value $K_{\text{распр}}$ is minimally necessary value of attenuation on route "jamming transmitter - working receiver". Knowing this value, on the nomogram, represented in Fig. 7.2, it is possible to determine the minimally necessary distance between the source of interferences and the working station, if radio waves are propagated in the free space.

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The effect of the Earth or tropospheric scattering on the radiowave propagation can be considered, after introducing into formula (7.9) attenuation factor by the V described method.

7.1.4. Calculation of the frequency separation between the interacting types of radio equipment with the assigned three-dimensional/space separation between them.

Frequently coincidence of carrying frequency of emissions of interacting stations creates interferences, for eliminating which is required large three- dimensional/space separation, not feasible for different (for example, tactical) reasons. In this case the condition of the absence of interferences $K_{\text{тр}} \leqslant K_{\text{расч}}$ is not satisfied, and therefore it is necessary to resort also to the frequency separation, which makes it possible to compensate the missing three-dimensional/space separation. For determining the required frequency separation it is necessary to know the actual value of the three- dimensional/space separation between the worker and by jamming stations. At this distance the jamming transmitter will create interference with the receiver of working station. The value of this interference is determined from formula (7.1).

Knowing assigned required ratio of signal to noise at input of receiver $K_{\text{тр}}$ and comparing it with $K_{\text{расч}}$ (it are determined, on the basis of assigned three-dimensional/space separation between interacting stations), should be determined value of minimum $K_{дсп\ мин}$, supplementary by frequency separation of interference of interference of that caused by nearness of interacting stations:

$$K_{доп\ мин}=K_{тр}-K_{расч}.$$

In terms of obtained value of weakening $K_{доп\ мин}$ it is possible to determine necessary frequency separation between interacting stations. It is located through selectivity curve of receiver.

7.2. APPLICATION OF SIMULATION IN RES EMS REGION.

In RES EMS region are used different forms of simulation [3].

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One of them, for example, is used for analysis of electromagnetic situation. In it digital computers are used for accelerating the analysis of reduced data. Another model is intended for so-called duel operation, when one transmitter which is the source of interference and one receiver on which acts this interference are examined. During the analysis are utilized following data: the direction of radiation of the antenna of transmitter, the characteristic of the minor lobes of its radiation pattern, the spectral density of radiated power, the sensitivity of receiver in the service band of frequencies, threshold signal and image of interference on the screen/shield of display unit (for radar). One should emphasize that for solving all problems, connected with questions of electromagnetic compatibility, the required quantity of such models must be equal to the number of in principle different types of equipment. Is used the series/row of auxiliary models, such, for example, as models for the imitation of the diverse conditions for radiowave propagation.

7.2.1. Elimination model.

Let us pause at short examination of so-called elimination model. It simulates the worst conditions for the work of radio-electronic means and it makes it possible to isolate among a large quantity of RES in question only those, which can work without interferences. This model (Fig. 7.10a) utilizes auxiliary devices/equipment and is the mathematical description (in the form of equations) of characteristics of RES and its electromagnetic situation. This model makes it possible to imitate the work of 12 thousand radio transmitters, placed over the area about $6.5 \cdot 10^3$ km^2.

Flowchart of computations with the aid of this model is shown in Fig. 7.10b. The input information of unit 1 of control of noise, which comes from the considered transmitter and receiver, is developed on the base of working characteristics of the latter (among other things of their arrangement and operating frequencies), and also on the basis of the data of spectral card indices, in which are recorded the parameters of each radio installation, which affect of EMS.

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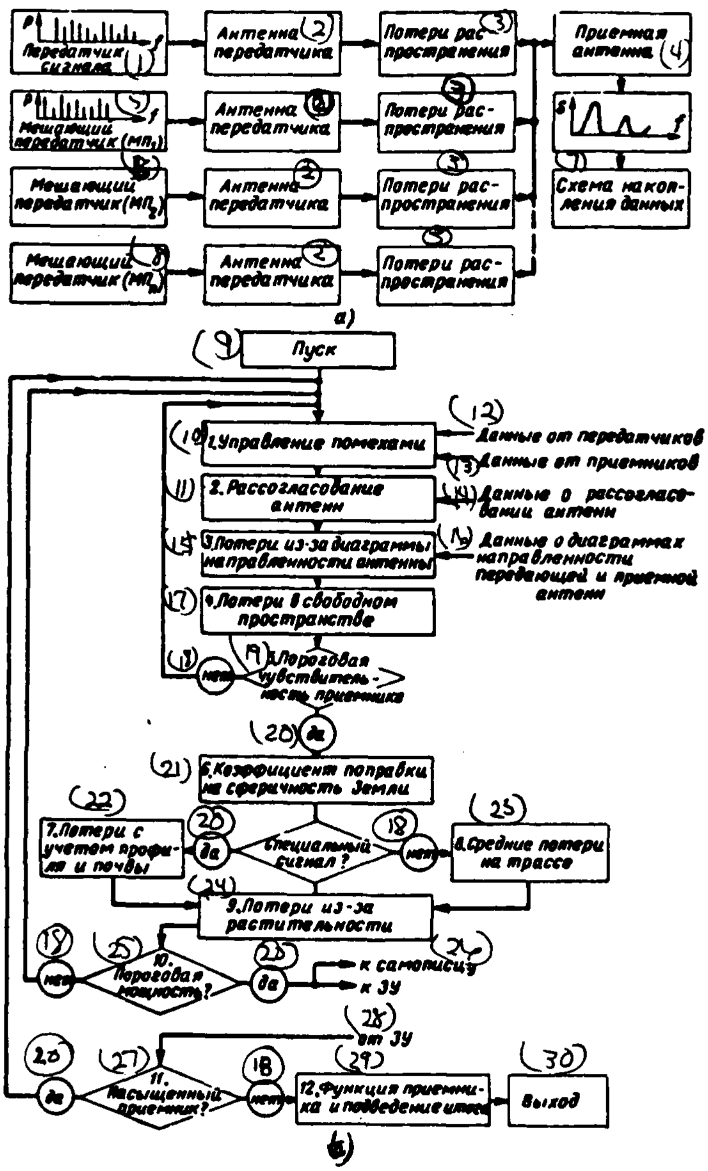

Fig. 7.10. Transmitter of signal. (2). Antenna of transmitter. (3). Losses of propagation. (4). Receiving antenna. (5). Jamming transmitter (MP_1). (6). Jamming transmitter (MP_2). (7). Diagram of accumulation of data. (8). Jamming transmitter .... (9). Empty. (10). Control of interferences. (11). Disagreement/mismatch of antennas. (12). Data from transmitters. (13). Data from receivers. (14). Data about mismatch of antennas. (15). Noise due to antenna

radiation pattern. (16). Data about radiation patterns of transmitting and receiving antennas. (17). Losses in free space. (18). no. (19). Threshold sensitivity of receiver. (20). yes. (21). Coefficient of correction for sphericity of Earth. (22). Losses taking into account of profile/airfoil and soil. (23). Average/mean losses on route. (24). Losses due to vegetation. (25). Threshold power. (26). Self recorder. (27). Saturated receiver. (28). from memory. (29). Function of receiver and leading up to total. (30). output.

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The control unit, after processing of spectral data of receivers, puts out the numerical value of the frequencies of the transmission of receivers and intermodulation frequencies, and also the value of the interfering frequencies, which can pass into the receiver along the fundamental and supplementary channels of reception/procedure. These values of frequencies and value of the sensitivity of receivers are introduced into the device of memory of calculator. After this, the control unit "studies" spectral characteristics of one of the jamming transmitters, for example MP_1 and compares them with the frequencies of the transmission of receivers, which are stored in storage cells. If none of the frequencies of jamming transmitter coincides not with one of the frequencies of storage cells, the control unit eliminates this transmitter from further analysis as the source, which does not present danger, and it investigates thus spectral characteristics of other jamming transmitters. But if one or the more spectral components of the jamming transmitter in question they coincide with one of the frequencies, stored in storage cells, then this indicates the danger of the appearance of interferences, and each of such suspicious spectral components of transmitters alternately is supplied to unit 2 of mismatch of antennas for the more in-depth analysis. In this unit is introduced the loss factor, which decreases the value of the power of each frequency component of transmitter, transmitted from the control unit. The coefficient indicated should only be input when in the spectral service records of transmitters losses in the feeders and disagreement/mismatch of antenna and transmitter were not fixed/recorded. These losses can significantly influence radiation level at frequencies, different from the carrier frequency, and therefore to the advisability of its further examination in the model.

Then interfering signal enters unit 3, where value of signal in accordance with radiation patterns and mutual orientation of transmitting and receiving antennas is corrected. As a result to the input of unit 4 enters the signal of this power, which would be removed/taken from the output of receiving antenna in the absence of losses on the route of the emission of the signal from the transmitter to the receiver, i.e., the signal of jamming transmitter, which arrived at the input of receiver during the free-space propagation.

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In this unit are considered the propagation loss of radio-will in the free space, therefore, the power of signal at its output is equivalent to power input of receiver during the emission of the signal of the frequency component of transmitter in the free space in question.

This power enters at input of comparator (unit 5), where it is compared with threshold sensitivity of receiver. If the power of this component does not exceed this sensitivity, then spectral component cannot show/render interference on the received signal and is eliminated from further examination. The corresponding information enters the control unit of interferences 1, which begins the new cycle of work.

However, into control unit enters new "dangerous" frequency component of first jamming transmitter MP_1. After all frequency components of this transmitter will be analyzed, begins the comparison of the frequencies of the components of another jamming transmitter, for example MP_2 with the frequencies, recorded in storage cells. In such a case, when one of spectral components, which entered into the comparator (unit 5), proves to be according to the power more than than the threshold of response of receiver, then it enters the input unit 6 for future reference analysis.

In unit 6 propagation losses are more precisely formulated. While in unit 4 it was assumed that the radiowave propagation occurs in the free space, then in unit 6 the sphericity of the Earth is considered. This refinement, as a rule, decreases level value of the interfering power, which enters the receiver. From the output of unit

6 signal comes into unit 7 or 8. If the analyzed signal is special, for example by the signal of the carrier frequency of working transmitter, then it enters the input of unit 7. But if the analyzed signal is interfering, then it brings to the input of unit 8. In unit 7 in detail are analyzed losses on the route of propagation taking into account the characteristics of the earth's surface (profile of locality/terrain and soil).

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Unit 8 is intended for processing of all other signals and considers only average/mean losses on the route (it is assumed that under the actual conditions the interfering signals come from any any direction and that therefore it is not possible to produce a precise account of propagation loss). The analyzed signal enters then unit 9, which considers the factor of the losses, caused by vegetation on the route of propagation, then - to the second comparator (unit 10). It, as the first comparator (unit 5), compares the level of the power of signal with the threshold sensitivity of receiver. If the level of power less or is equal to threshold sensitivity, which means that the signal cannot create interference; jamming transmitter is eliminated from further examination, and in the control unit is examined another interfering signal in the already described order. But if the power of signal exceeds threshold sensitivity, then this indicates the possibility of interference; therefore information about the character of this signal is written/recorded and then it is analyzed no longer by machine, but by man.

Together with recording, information about that interfering of signal "is memorized" in memory unit. During the subsequent analysis of interference effect on the quality of the transmission of useful information the "memory" about the interfering signal gives the possibility to establish/install the dependence between the quality of the transmission of useful signal and the value and the character of the interfering signal.

After termination of analysis of all components of signals, which prevent work of receiver, these signals are summarized together with useful and are supplied to third comparator (unit 11). If total power exceeds the level of the saturation of receiver or the upper limit of its dynamic range, then the receiver will not be able normally to work, about which at the input of the control unit of interferences will report the third comparator. But if total power does not exceed the limits indicated, then signals enter unit 12, which realizes functions of receiver. Making the part of the program of the computer, which imitates demodulation in the receiver, and determining the quality of the work of system, i.e., the quality of the transmission of information, this block complete the examination of the effect of interfering component.

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Principle of work of described model simplifies and accelerates forecast of interferences. for example, if one assumes that 15000 potential sources of interferences threaten receiver and which creates each of them on 10 interfering signals, then in this case in the absence of the limiting second and third comparators model would be obligated to carry out the complete analysis of all 150000 transmitted signals. If we consider that the complete analysis of one signal is realized in 1 minute, then to this analysis would be required 2500 working hours. In the presence of these blocks all signals are analyzed by model into three stages.

During the first stage computer selects of all emitters only those, which actually can be sources of interferences. In the second stage the remaining potentially interfering sources undergo more careful analysis for the purpose of the selection of that part of the sources, which will prove to be determining for the electromagnetic compatibility. Only the remaining sources (order 1-2% of an initial quantity) will require more serious analysis and their even smaller number - organizational and technical measures for guaranteeing their electromagnetic compatibility.

Further development of simulation with more effective application of computers will contribute to more qualitative and more rapid analysis of EMS of RES.

7.2.2. Simulation of electromagnetic control of interferences on the receiver.

Simulation under laboratory conditions of electromagnetic control on receiver of useful and background radiation [3] is one of methods of analysis of electromagnetic compatibility of RES.

Fig. 7.11 gives block diagram of simulation of electromagnetic situation for radiolink system and functional test of latter in conditions of interferences. Radiolink system consists of 6 blocks (second series/row on top, except summator). In the model is imitated "environment" for the system being investigated and the ability of this system to transmit information with the tolerance level of distortion is checked in this environment/encirclement.

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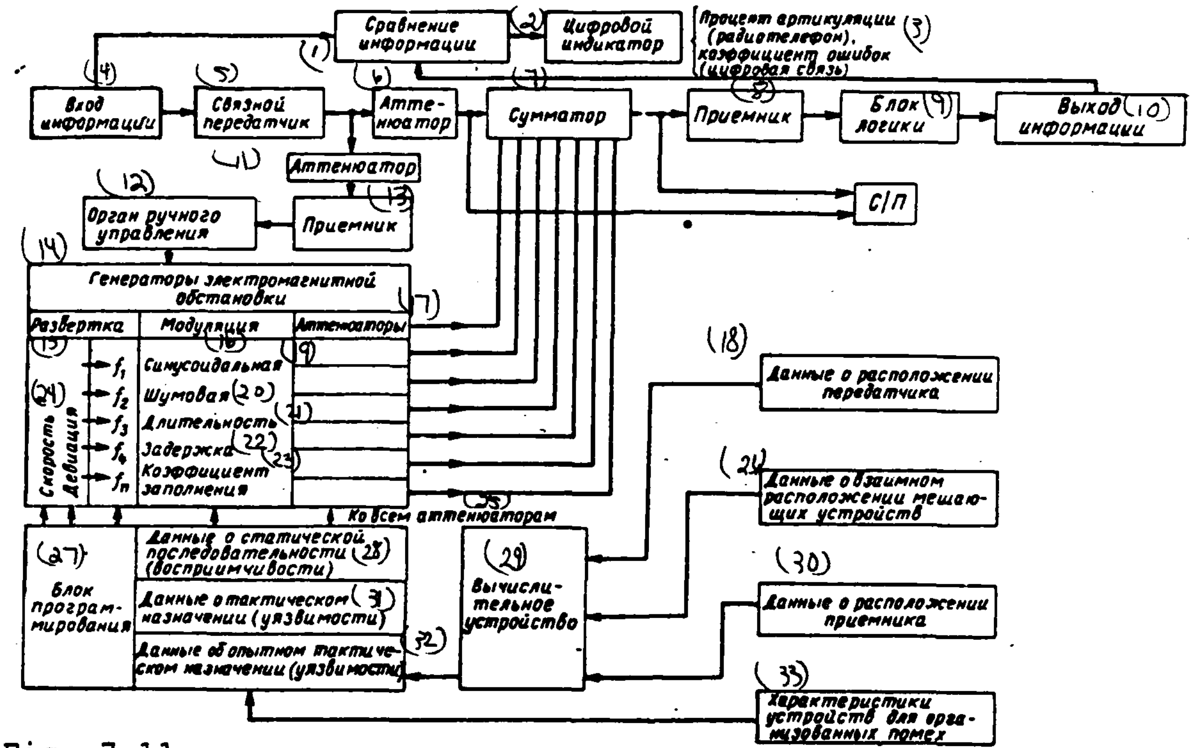

Fig. 7.11.

Key: (1). Comparison of information. (2). Digital indicator. (3). Percentage of articulation (radiotelephone), error coefficient (digital connection/communication). (4). Input of information. (5). Connected transmitter. (6). Attenuator. (7). Summator. (8). Receiver. (9). Block of logic. (10). Output of information. (11). Attenuator. (12). Manual control unit. (13). Receiver. (14). Generators of electromagnetic situation. (15). Scanning/sweep. (16). Modulation. (17). Attenuators. (18). Data about arrangement of transmitter. (19). Sinusoidal. (20). Noise. (21). Duration. (22). Delay. (23). Duty factor. (24). Speed deviation. (25). To all attenuators. (26). Data about relative position of interfering devices/equipment. (27). Programming unit. (28). Data about static sequence (receptivity). (29). Computer. (30). Data about arrangement of receiver. (31). Data about tactical designation (vulnerability). (32). Data about experimental tactical designation/purpose (vulnerability). (33). Characteristics of devices/equipment for electronic jamming.

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Data about characteristics of transmitter and receiver, about mutual arrangement of interfering devices/equipment, recorded on magnetic tape, are supplied to computer of model, whose output is connected with block of programming. The latter controls the work of the generators of the electromagnetic situation, whose signals are equivalent to the signals of the radio-electronic means, which affect this system. These interfering signals together with the useful signal of transmitter enter the summator, and from there - to the input of receiver. The interference shielding of the communication system is rated/estimated by digital indicator via the comparison of the information, which entered the input of the transmitter of the communication system, with the information, which passed together with the interfering signals to receiving circuit. It is natural that in this case is considered weakening the signal, emitted by transmitter, during its propagation, and also signal distortion both in that transmitting and in the receiving circuits.

Block c/n serves for determining the sensitivity of receiver to interferences. It measures the relation signal/noise at the input of receiver. The comparison of this relation with readings/indications of digital indicator characterizes noise immunity of system. If, for example, block c/n shows a small relation signal/noise, and digital indicator in this case indicated the high degree of articulation (for the radio communication system), then this means that the system of communication is low-sensitivity to the interferences. Noise immunity of system, which can undergo the effect of the interferences of different types, is rated/estimated by a series of the values, shown by digital indicator and unit c/n. The communication system tests by alternations in the input information and composition of the interfering generators how are imitated different actual conditions for work. These tests give the possibility to determine the interference shielding of system from different radio interferences with its work under different conditions.

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8. SOME QUESTIONS OF ELECTROMAGNETIC COMPATIBILITY.

Let us note number of questions, to which, in the opinion of author, one should focus attention during solution of problems of EMS of RES. They include the following.

1. Development of criteria of electromagnetic compatibility of radio-electronic means of different designation/purpose. By criteria of EMS, naturally, are understood the requirements for the quantitative characteristics (parameters) of RES, with which is provided EMS of the latter, and also the requirement and to the quantitative characteristics of the medium, in which are propagated the radio waves, and to the time, frequency and space separations between RES.

2. Normalization of parameters of RES, which are determined from EMS. All parameters of EMS must be calibrated in such a way that the totality of norms could ensure EMS of RES.

One should say that soon, apparently, hardly it will be possible to completely solve problem of EMS due to normalization of parameters of RES due to limitedness of technical and economic possibilities. It would be more correct to maintain the sufficiently low level of radio interference, attained on the contemporary level of radio engineering and legalized by the appropriate solution, and compensate for the missing attenuation of interference by using other methods of reduction of the mutual effect of RES, for example due to the frequency and three-dimensional/space separations.

Besides parameters of EMS of RES, fundamental importance has normalization of background radiation of generator vacuum-tube instruments.

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3. Determination of necessary signal/noise ratio at input of receiving device, upon which is provided normal operation of latter, is required with quantitative estimation of electromagnetic compatibility of RES. It is necessary to keep in mind that for different forms of modulation of useful and interfering signals, with the noncoincidence of the carrier frequencies of interfering RES, with the difference between the value of the radiation spectrum of the interfering signals and the passband of working receivers, for different receivers, etc., the value of the required relation signal/noise is the function of the enumerated factors or their part, and therefore its determination - a very complicated problem. Will be required, apparently, the development of the principles of the classification of receivers for the classes, each of which will have its values of the necessary relation signal/noise at the input of receiver, and then - serious scientific research and experimental-design work.

4. Account of weakening signal and interference during radiowave propagation. Are necessary widespread investigations into the regions of radiowave propagation, associated with predicting the EMS of RES in different geographical areas. From it is necessary to carry out, since the frequency characteristics of the troposphere and ionosphere and underlying surfaces (taking into account artificial and natural barriers/obstacles) during the radiowave propagation simultaneously at the operating frequency of RES and at the possible interfering frequencies are incomplete.

5. Development of vacuum-tube instruments with lowered/reduced level of supplementary and continuous emissions is necessary because these emissions create main difficulties during construction and design of radio-electronic means, they make it necessary to increase their overall sizes and weight. Such vacuum-tube instruments include the klystrons, magnetrons, LOV, LBV, amplitrons, mitrons. Usually the power of the harmonics of klystrons is of below power of fundamental frequency to the value, which varies from 25 to 40 dB. The power of the second and third harmonics of magnetrons can be up to 40 and 20 dB with respect lower power of fundamental oscillation. The power of the second and third harmonics of rest of the enumerated classes of instruments to 20-40 dB is lower than the power of the fundamental oscillation (it should be noted that in the near frequency zone the levels of the spurious radiations of the separate classes of vacuum-tube instruments considerably differ from each other).

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6. Search of technical ways of reduction in mutual radio interferences in radio equipment relates, mainly, to antennas (due to improvement in frequency characteristics and three-dimensional/space radiation patterns, with which emission not nonoperative frequencies and in all directions, with exception of major lobe, they decrease to technical attainable and economically advisable level); to by generator vacuum-tube instrument; to net power, supplied to antenna (due to its maximum limitation to value, which ensures fulfillment of tactical mission); to frequency stability of generators of transmitting devices and heterodynes of radio receiving equipment, which affects probability of frequency coincidences, or probability of out-of-band reception; to transmitters (due to decrease in level of supplementary and out-of-band emissions); to the receivers (due to the decrease of the sensitivity of equipment to the effect of different kind of interferences with the aid of the selection and working/treatment of signals, etc.), to the feed circuits (due to decoupling between RES, filtration, etc.), etc.

7. Development and introduction into radio-electronic means of special technical devices/equipment, which raise their protection from radio interferences. It is here appropriate to say that the suppression or the decrease of radio interferences usually is examined from two points of view. On one hand, they attempt to prevent or to limit background radiation and their propagation. On the other hand, they attempt to decrease the sensitivity of radio-electronic means to

the radio interferences with their reception. For this they develop and introduce into radio- electronic equipment filters and screens, and also they develop and introduce special circuit designs, etc.

FOOTNOTE 8. Performing work, connected with searches for new principles of design of transmitting and receiving devices, which make it possible to reduce the level of supplementary and out-of-band emissions and by the sensitivity of the channels of supplementary reception, respectively, and also work, connected with the decrease of the occupied frequency band.

9. Examination of possibility of designing of single procedure of calculation of mutual radio interferences between different radio-electronic means. In recent years for the evaluation/estimate of mutual radio interferences were developed the nomograms, the graphs/curves and other booster agents, which accelerate similar calculations.

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However, single method of the calculation of the mutual radio interference, created by different radio equipment, there does not exist. There are only particular procedures of the engineering calculations of three- dimensional/space or frequency (or that, etc.) separations, with which the interferences virtually do not affect not the passage of useful signal in the receiving circuit; the methods of determining the parasitic frequencies, which appear during mixing in the receiver of two high-frequency signals; the methods of determining the signal/noise ratio at the input of receiver, etc. Therefore it is necessary to examine the possibility of designing of the single procedure of calculation of mutual radio interferences between the radio-electronic means of different designation/purpose.

It is completely probable that it will prove to be impossible to develop procedure of calculation of interferences single for all RES. In this case one should try to have a series of procedures, which must make it possible to design the level of interferences and to provide their forecasting. In this case it is necessary to consider the electromagnetic situation, created by all radio-electronic means, located in the area in question, and also the possible change in this situation, caused on maneuvering the interacting means. This task is very complicated and labor-consuming.

10. Use of mathematical and physical simulation for forecasting of character and level mutually-leg interaction between RES, and also for solving other questions of EMS.

11. Development of methods of special measurements, necessary for solving problems of EMS. Measurement in the broadband, equal to several octaves, such parameters as the supplementary and out-of-band emissions of transmitters and vacuum-tube generator instruments, the sensitivity of receivers along the channels of supplementary reception, the selectivity of receivers, etc., and also the need for

the large number (to tens of thousands) of such measurements require the development of the methods of special measurements. The specific character of such measurements besides the usual requirements of small overall sizes, weights, required power and low cost/value of instruments are also higher accuracy, speed and measurement accuracy, than obtained into present, time, higher threshold of response, etc.

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Requires improvement the new method of measurements - automatic scanning of the frequency spectrum and the recording of data of scanning. At present begins work on the use of artificial Earth satellites for level measurement of the radio interferences and other parameters of EMS.

12. Development and production of special measuring equipment, necessary for solving problems of EMS. For fulfilling the requirements stated in the preceding section, special measuring equipment is necessary besides that already in existence. It includes spectrum analyzers, which make it possible to obtain the graphic representation of entire spectrum of signal (and useful, and interfering), radio-noises meter) to 1000 MHz), instruments for the removal/taking and the automatic construction of different frequency characteristics of RES, three-dimensional/space antenna radiation patterns, etc.

13. Creation of theory of electromagnetic compatibility of

radio-electronic means. It is possible to assume that conducting large number of works in the region of EMS it will prevent the absence of the theory of electromagnetic compatibility of RES. This theory, obviously, in the course of time, after conducting many particular works, will be developed. Today it is possible to only assume that into it must enter the complex examination of such questions as simultaneous effect on RES and on the grouping of RES with the different probability of the series/row of the background radiation: from their own RES, from analogous RES of the countries, bordering on the USSR, industrial radio interferences, etc.

14. Development of optimum technical-economic resolutions of problem of decreasing the level industrial of radio interferences. This question is considerable with the resolution of the problem of the decrease of the level of industrial radio interferences. Development and introduction into the national economy of new machines, mechanisms, apparatuses and instruments, which are the source of industrial radio interferences, require the inclusion in their construction/design as organic whole, noise suppressors (devices/equipment, which we could accomplish the all-Union norms of the permissible man-made interferences with radio reception).

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Consequently, it is necessary to conduct work so that, on one hand, would be made norms, and on the other, so that would be minimum the rise in price of output. Therefore should be considered the material expenditures, connected with development and production of the shielded locations and cabins of the most varied designation/purpose, and also another necessary accessory equipment.

15. Establishment of order of accumulation, collection, generalization, analysis, storage and use of information about technical parameters of RES, necessary for preparation for organizational (tactical) and technical actions for providing EMS of concrete/specific RES or groupings of RES. For this it will be necessary to deeply investigate (theoretically and experimentally) the parameters of EMS, necessary for the quantitative estimation and forecasting EMS of RES; one should strive so that all radio-electronic means and generator vacuum-tube instruments would be produced by manufacturers with spectral certificates, in which must be indicated all parameters of EMS. After ensuring, thus, all necessary parameters of RES, after using mathematical and physical simulation and frequency charts, it is possible to calculate (to forecast) the level of interferences and to make organizational (tactical) and technical recommendations.

16. Training in higher and secondary special schools of radio specialists for solution of questions of electromagnetic compatibility of radio-electronic means. It is necessary already in the stage of instruction in the higher and secondary special schools to train the personnel of technical-engineering workers for the economical use of radio frequencies as national riches, for the skill in engineering

solution of the problems, connected with the guarantee of an electromagnetic compatibility of radio-electronic means. It should be noted that at present is not yet developed the program of study, are limited the operating instructions on the teaching of questions of EMS of RES, there is neither monographs nor textbooks. True, separate questions of the problem of EMS of RES (stability, frequency, filtration, improvement of the directional properties of antennas, radiowave propagation, etc.) partially they are illuminated in the available literature, and also they are taught in the educational institutions, but not in connection with problem of EMS.

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17. Economic investigations, connected with solution of problem of EMS of RES. They must be carried out for determining the expenditures when providing EMS. One ought not to be guided by the requirement of unconditional electromagnetic compatibility only due to the equipment method, since this can lead to the large economic losses. In order to avoid them, should be accepted optimal solution for providing EMS: partially due to the equipment modification with additional material expenditures, partially due to the frequency, time and spatial separations, which do not require high expenditures.

18. Creation of terminology in region of radio emissions and their reception.

APPENDIX. Classification of range of radio frequencies and radio waves.

(1) Диапазон радиочастот				(2) Диапазон радиоволн			(6) Нерекомендуемые термины
(2) Наименование диапазона			(5) Границы диапазона	(2) Наименование диапазона		(5) Границы диапазона	
(3) Основной термин	(4) Параллельный термин: (7) Полное наименование	(8) Сокращенное наименование		(3) Основной термин	(9) Параллельный термин		
1-й	Крайние низкие частоты (10)	КНЧ	От 3 до 30 гц включительно (11)	1-й	Декамегаметровые волны (12)	От 100 000 до 10 000 км включительно (13)	
2-й	Сверхнизкие частоты (14)	СНЧ	От 30 до 300 гц включительно (11)	2-й	(15) Мегаметровые волны	От 10 000 до 1 000 км включительно (13)	
3-й	Инфранизкие частоты (16)	ИНЧ	От 300 до 3000 гц включительно	3-й	(17) Гектокилометровые волны	От 1 000 до 100 км включительно (13)	
4-й	Очень низкие частоты (18)	ОНЧ	От 3 до 30 кгц включительно (19)	4-й	(20) Мириаметровые волны	От 100 до 10 км включительно (13)	(23) Сверхдлинные волны (СДВ)
5-й	Низкие частоты (21)	НЧ	От 30 до 300 кгц включительно (19)	5-й	(22) Километровые волны	От 10 до 1 км включительно (13)	(24) Длинные волны (ДВ)
6-й	Средние частоты (25)	СЧ	От 300 до 3000 кгц включительно (19)	6-й	(26) Гектометровые волны	От 1000 до 100 м включительно (27)	Средние волны (СВ) (28)
7-й	Высокие частоты (29)	ВЧ	От 3 до 30 Мгц включительно (33)	7-й	(30) Декаметровые волны	От 100 до 10 м включительно (27)	Короткие волны (КВ) (31)
8-й	Очень высокие частоты (32)	ОВЧ	От 30 до 300 Мгц включительно (33)	8-й	(34) Метровые волны	От 10 до 1 м включительно (27)	—
9-й	Ультравысокие частоты (36)	УВЧ	От 300 до 3000 Мгц включительно (33)	9-й	(35) Дециметровые волны	От 100 до 10 см включительно (38)	—
10-й	Сверхвысокие частоты (39)	СВЧ	От 3 до 30 Ггц включительно (40)	10-й	(37) Сантиметровые волны	От 10 до 1 см включительно (38)	—
11-й	Крайне высокие частоты (43)	КВЧ	От 30 до 300 Ггц включительно (40)	11-й	(41) Миллиметровые волны	От 10 до 1 мм включительно (42)	—
12-й	Гипервысокие частоты (46)	ГВЧ	От 300 до 3000 Ггц включительно (40)	12-й	(44) Децимиллиметровые волны	От 1 до 0,1 мм включительно (42)	(45) Субмиллиметровые волны

Key: (1). Range of radio frequencies. (2). Designation of range. (3). Fundamental term. (4). Parallel term. (5). Boundaries of range. (6). Unrecommended terms. (7). Complete designation. (8). Abbreviated designation. (9). Parallel term. (10). Extremely low frequencies. (11). From... to ... Hz inclusively. (12). Decameter waves. (13). From ... to ... km inclusively. (14). Ultralow frequencies. (15). Mega-meter waves. (16). Infra-low frequencies. (17). Hecto-kilometer waves. (18). Very low frequencies. (19). From ... to ... kHz inclusively. (20). Myriameter waves. (21). Low frequencies. (22). Kilometer waves. (23). Very long waves (SDV). (24). Long waves (DV). (25). Medium frequencies. (26). Hectometer waves. (27). From ... to ... m inclusively. (28). Medium-frequency waves (SV). (29). High frequencies. (30). Decametric waves. (31). Short waves (KV). (32). Very high frequencies. (33). From ... to ... MHz inclusively. (34). Ultrashort waves. (35). Decimeter waves. (36). Ultrahigh frequencies. (37). Microwaves. (38). From ... to ... cm inclusively. (39). Superhigh frequencies. (40). From ... to... GHz inclusively. (41). Millimeter waves. (42). From ... to ... mm inclusively. (43). Extremely high frequencies. (44). Submillimetric waves. (45). Submillimeter waves. (46). Hyper-high frequencies.

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